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Report ~~of the~~

~~TWENTY-THIRD~~ SOUTHERN PASTURE AND FORAGE CROP

IMPROVEMENT CONFERENCE

Virginia Polytechnic Institute
Blacksburg, Virginia

June 14-15, 1966 X

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Service
Crops Research Division

CR-68-66

Report of the

TWENTY-THIRD SOUTHERN PASTURE AND FORAGE CROP IMPROVEMENT CONFERENCE[1/]

Virginia Polytechnic Institute
Blacksburg, Virginia
June 14-15, 1966

PROGRAM

Tuesday - June 14 Morning
Agricultural Auditorium - Smyth Hall
Chairman W. B. Anthony, Auburn University, Presiding

Tuesday - June 14 - Afternoon

1:30 to 5:00 Research Tour

1/ Reported by: R. C. Leffel, Permanent Secretary, USDA, Beltsville, Maryland

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Tuesday - June 14 - Evening

Wednesday - June 15 - Morning
ANIMAL SCIENCE INTEREST GROUP
Dairy Auditorium - Saunders Hall
William Chalupa, Clemson University, Presiding

VOLUNTARY FOOD INTAKE IN RUMINANTS

PLANT BREEDING AND GENETICS INTEREST GROUP
Room 223, Biochemistry Building
R. C. Buckner, University of Kentucky, Presiding

Tuesday - June 14, 1966 - Morning

W. B. Anthony, Presiding

Opening Session

The twenty-third meeting of the Southern Pasture and Forage Crop Improvement Conference was opened by Conference Chairman, Dr. W. B. Anthony. The Invocation was given by Dr. C. Y. Ward. Chairman Anthony announced a Conference registration of 81 to date, and introduced all present by State, nation and industry.

Welcome to Virginia - Wilson B. Bell, Dean, College of Agriculture - Virginia Polytechnic Institute

Dr. Bell welcomed the Southern Pasture and Forage Crop Improvement Conference to Virginia, and announced that Dr. Hahn, President of Virginia Polytechnic Institute, could not attend the meeting as scheduled. Dr. Bell has pondered the role of Dean - and concludes - "The President does the talking; the Faculty does the thinking; the Dean should prevent the President from thinking and the Faculty from talking!"

Dr. Bell described the topography and geography of Virginia and the role of livestock and forage industries therein. Virginia Polytechnic Institute is the Land-Grant institution of Virginia, and contributes teaching, research, extension, and public service. The interdisciplinary approach is emphasized in current problems. The College of Agriculture is 1 of 6 colleges, with an enrollment of 750 students (10 to 12% of the total enrollment); 8300 students are expected fall of 1966; 1975 enrollment is estimated as 15,000. Urbanization and industrialization are stressed within the State, but agriculture is still vital; Virginia's economic development is based on, primarily: (1) industrial development, (2) tourism, and (3) agriculture. Virginia's Agricultural Experiment Station utilizes 12 field stations in the conduct of research vital to agriculture of Virginia.

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FORAGES IN VIRGINIA 1-9

Crop Production and Soil Use Patterns by - H. L. Dunton, Head, Agronomy Department, Virginia Polytechnic Institute and others

Dr. Dunton discussed patterns and trends in forage production in Virginia with a series of slides. The evolution in forage production and in agriculture emphasizes "rapid changes", "exactness", "higher yields", and "intensity". Changes must be predicted and farmers must be prepared to meet such changes. Costs of production are rising faster than yield increases; higher yields are defined in terms of maximum economic return. Intensity

of production refers to more feed per acre. In 1959, Virginia's farmland was utilized as follows: Forages, 75%; grain crops, 14%; and other field crops, 11%. Forage acreage is decreasing, with "tons of hay equivalent" rising rapidly. Alfalfa acreage increased rapidly from 1949 to 1959; the alfalfa weevil has curtailed production recently. Alfalfa production must be efficient, 3-1/2 tons/acre or more. Red clover production was predicted as a "decrease or little change"; red clover acreage has increased rapidly since infestation of alfalfa by the alfalfa weevil. This is a switch to a less intensive crop. Lespedeza acreage has decreased rapidly, and is expected to decrease further, because this crop cannot be intensified. Bluegrass pasture - "between forests and intensive crops" - offers no opportunity for intensification. Corn silage has increased rapidly; it offers more TDN per acre per year at lowest cost. Corn for grain has not increased greatly in Virginia. Thus we now find a tremendous competition between crops; competition takes place on each soil type. Production in the future will emphasize a specific crop on a specific soil.

FORAGES IN VIRGINIA

Livestock Production Areas and Patterns - C. Curtis Mast, Animal Science Department, Virginia Polytechnic Institute

Mr. Mast utilized 1964 census data and described the past, present, and projected statistics on livestock numbers, forages, and cash receipts, for each of the following production areas of Virginia: (1) Western mountain area; (2) Shenandoah Valley: (3) Piedmont south of the James River; (4) Piedmont north of the James River; (5) Coastal south of the James River; and (6) Coastal north of the James River.

FORAGES IN VIRGINIA

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Dairy Cattle Feeding Patterns - W. R. Murley

In recent years in Virginia the feeding of dairy cattle has changed tremendously. My remarks will be centered around these changes that have taken place in recent years--an increase in silage and grain feeding and a decrease in hay and pasture feeding. The greatest increase has been the feeding of corn silage to dairy cattle in Virginia. A lot of this has been brought about by adverse weather conditions as well as the effect that the alfalfa weevil has had on alfalfa production. Furthermore, corn silage has the potential of yielding more nutrients per acre at the lowest cost per nutrient and the highest profit per acre of any harvested feed crop grown in Virginia. Corn silage is also a high quality, palatable, and otherwise desirable forage when properly made and fed in balanced rations. Furthermore, it has been demonstrated that high levels of production can be maintained when an all corn silage forage program is followed.

Because of the favorable position that corn silage has taken in the feeding of dairy herds in Virginia, the Extension Service has promoted the production of corn silage. Major accomplishments in the program have been indicated by an increase in the amount of silage that has been made by about 85% since 1959. This is indicated in Table 1.

TABLE 1. Corn Silage Production in Virginia

	1959		1965
Tons	1,210,000	85.9% Increase	2,249,000
Yields/Acre	11 Tons		13 Tons
Acres	110,000		173,000

This increase has been brought about through an educational program on forage production, harvesting, and storage. The main items that have been promoted have been the choice of proper varieties, the rates of planting, amount of fertilizer to use, and an extensive weed control program.

Another indication of the results of a promotional program has been the improvement in the quality of silage as measured by the V.P.I. Forage Testing Program since 1963. Table 2 shows the dry matter content as well as the nutritive value of the corn silage has improved during this time. This improvement in quality has come about as the result of farmer experience and also a stepped up research program at V.P.I. on what makes a quality corn silage.

TABLE 2. Improved Quality of Corn Silage in Virginia

	1963	1965
Dry Matter %	29.2	33.6
T.D.N. %	19.6	22.8

One of these particular studies has been on the stage of maturity at harvest time and according to Table 3 dairymen and livestock producers have switched to a more mature silage. Apparently the hard dough stage is much better than any stage where less maturity is prevalent.

TABLE 3. Stage of Maturity at Harvest (V.P.I. Forage Testing Program)

Stage	1962-63	1964-65
	%	%
Milk	4.3	1.4
Soft Dough	32.7	14.6
Hard Dough	58.8	66.1
Mature	3.7	9.9

Another indication of the change in feeding patterns in Virginia is brought out by our DHIA production testing program in which we have about 1,000 herds or over 45% of our Grade A dairymen enrolled. Table 4 shows that silage consumption has been more than doubled in the last 10 years with a corresponding decrease in hay and pasture that is being fed. Also, there has been an increase in the amount of grain fed per cow. Along with this has been a very substantial increase in the production per cow.

TABLE 4. Virginia DHIA Trends

	1955	1965
Grain	2807	4700
Silage	6191	14000
Hay	3110	1900
Pasture (Days)	208	179
Milk	8867	11834

As I indicated, the promotional program for corn silage has been accelerated by some of the research work done at V.P.I. Table 5 shows one piece of this work where stages of maturity of corn silage were studied. A much better response was obtained where more mature corn silage was fed.

TABLE 5. Maturity of Corn Silage
(V.P.I. 1962-63)

Stage	Milk (Lbs./Day)	Dry Matter (%)	Intake (Lbs. D.M./Day) (Per cwt body weight)
Soft Dough	38.7	25	1.95
Medium Dough	41.5	30	2.13
Hard Dough	42.6	33	2.31

Further work is being continued on the use of corn silage in dairy cattle rations in an attempt to continue to find ways of making it even a better feed for dairy cattle. Recently there has been a push on by the equipment manufacturing people to sell a forage harvester that will cut the silage finer than the conventional harvesting equipment. This is an attempt to prevent the more mature grains of corn from passing through the animal undigested. Table 6 will show the results of a study where silage was re-cut prior to being blown into the silo where the size of particles was about 1/2 inch or less in size. The main difference in response of cows when fed this type silage as contrasted to regular silage was the tremendous drop in butterfat test from the first to the tenth week of the trial. This drop could not be tolerated by dairymen who are selling their milk on the basis of the butterfat content. Perhaps this silage was cut too fine and more work needs to be done along this line. Perhaps there is a more optimum length of cut than we have found so far.

TABLE 6. Effect of Re-Cut Silage (35% D.M.)
(V.P.I., 1966)

	Control	Re-Cut
Number Cows	16	16
Silage Dry Matter Intake (Lbs./Day)	24.2	21.9
Milk (Lbs./Day)	46.0	46.4
Fat Test (%) (10th Week)	3.5	3.0
D.M. Voided (Whole Kernels) (Lbs.)	1.1	0.2

Corn silage is low in protein and when dairymen shift from feeding of some alfalfa hay in their ration to a very heavy corn silage feeding program they must shift to a higher than the conventional 16% concentrate mixture. Table 7 shows the response of dairy cows when fed corn silages that had urea added to it. This again is some recent research at V.P.I. in an attempt to find out how to improve the quality of corn silage and make it a more desirable feed for dairy cows. The results of this study coincide with results from other stations and because of the uniformity of results from different locations we are recommending that 10 pounds of urea be added per ton of corn silage. When this is done the dairyman can reduce his concentrate mixture to about 13% total protein which should

be a lower cost concentrate mixture than the conventional 16 or 18%.

TABLE 7. Response of Dairy Cows When Fed Corn Silage With Urea Added (Huber, V.P.I., 1966)

	Levels of Urea Per Ton of Silage (Lbs.)		
	0	10	15
Number of Cows	8	8	8
Milk (Lbs./Day)	46	44	48
Intake (Dry Matter) (Lbs./Day)	24.6	23.3	24.1
Percent of Grain Mixture Fed	18	13.3	10.7

A caution of course on the feeding of urea has to be that there is an upper limit beyond which you will get a depression in intake of silage and a corresponding depression in milk production. Recent research work at V.P.I. indicates that when 40% of the total nitrogen comes from urea, there is a decided decrease in intake of silage and also in production by the animals. In fact, there was even a decrease when 20% of the total protein came from urea. More recent work indicates that at the 10% level of total protein coming from urea there is no depression in milk production. So apparently somewhere between 10 and 20% is the optimum level.

TABLE 8 UREA IN DAIRY RATIONS

% of Total Protein	% Urea in Concentrate	Milk/Day
0	0	50.4
10	1.1	49.7
20	2.2	46.4

FORAGES IN VIRGINIA

Research Facilities for Forage and Livestock - Coyt. T. Wilson

I have heard that most people remember pleasant events much more vividly and for longer periods of time than unpleasant events. Soldiers who have lived through the horrors of war are more likely to discuss the good times they had on weekend passes than the discomfort of a fox hole, the painful wounds that they received or the destruction of life and property that they witnessed.

I suspect that most of us occasionally close our eyes and dream of the "good old days" when things were less hectic than they are at present-- when problems were not so difficult-- and when it was possible to find a little leisure time for fishing, golfing, hunting or just visiting with the family.

Whatever it is that causes us to remember pleasant things more readily than unpleasant things also causes us to forget how much progress we have made in forage and livestock research and the difficulties under which this progress was made. There are so many unanswered questions today that we are tempted to say that nothing has been accomplished. Our need for more and better facilities is so great that we are tempted to conclude that we are not as well off as we were a few years ago. When these temptations come our way we need to learn to say, "Get behind me, Satan." Our progress has been as rapid as that of the space program even though less dramatic. The facilities and the methodology that we use today bear but little resemblance to those in use before World War II.

About 30 years ago, Alabama farmers were informed that research at Auburn had shown that one acre of alfalfa would support one milk cow throughout the year. As I recall the story, someone fenced off a measured acre of alfalfa and turned a cow in to graze. When surplus growth occurred, it was mowed and stored as hay to be fed during the winter months. The point was stressed that the cow received only salt and water in addition to alfalfa that she grazed or consumed as hay. As far as I know, the cow was never weighed and no record was kept of the amount of milk or butterfat produced. Today we would not attempt to evaluate alfalfa as a forage if our facilities consisted of one nondescript cow, enought fencing to enclose one acre of alfalfa, and a No. 2 tub to serve as a water trough.

The early work on pasture fertilization was equally crude by today's standards. In some instances, the differences were so striking that there was no room for doubt. When the yield of beef per acre could be increased fourfold or more by applying phosphate to pasture, no one worried about replication, quality of beef produced, or the possibility of mineral imbalances. But all the work was not so dramatic. Even in the 1940's stories were circulated that cows could detect the difference between fertilized and unfertilized forages. Dean M. J. Funchess at Auburn was telling some of us once that he had visited one of the branch stations in Alabama where the Superintendent had fertilized part of a pasture seeded to serecia lespedeza. He said that the cows were grazing the fertilized portion "right up to the line where the fertilizer was applied." As far as he was concerned, this was proof that the fertilized serecia was more nutritious and more palatable than unfertilized serecia. Someone in the group suggested that the fertilized serecia sod might have more crabgrass and that the cows might be eating this in preference to the serecia, but this remark was ignored.

Stories like these could be multiplied, but the point that I want to emphasize is that as recent as 25 or 30 years ago our facilities for forage and livestock research were simple, often crude and wholly inadequate.

The regional research program made possible by the Research and Marketing Act of 1946 deserves a lot of credit for the improvements that have been made in both facilities and research methods. One of the early projects was S-12. Many of you served on that Technical Committee or on one of the four regional projects that grew out of it. I will not attempt to enumerate the contribution made by these groups. You know them better than I know them.

To me, one of the most significant developments has been the recognition that forage evaluation is exceedingly complex and that many disciplines must work together to find the answers to the questions that arise. All of you recognize that clipping and weighing forage from measured areas is not sufficient for evaluation. Botanical separations add something and proximate analyses add something more. But the final evaluation is in terms of costs and returns, and this requires animal performance data. To recognize and control the variables of soil, species, botanical composition of the sward, the chemical composition of the forage, all of the variables associated with the test animals and the variables of the soil and air is a tremendous task. You also have to recognize the human bias variable that is introduced by the scientist.

We do not claim that we have been any more successful at V.P.I. in recognizing and solving these problems than any other state. We have no facilities that are truly unique. We do have a certain amount of state pride, and we think that our forage research is pretty good. I would like to tell you a little about this program. In the first place it is a team effort involving scientists from the Departments of Agronomy, Animal Science, Biochemistry and Nutrition, and Dairy Science. The Departments of Entomology and of Plant Pathology and Physiology also become involved when disease, weed, or insect problems arise. These men provide the brains to generate ideas. The diversity of specialized training enables them to provide a variety of skills. Their willingness to work together makes possible a more efficient utilization of their brains and their skills.

We have at Blacksburg the usual assortment of pastures, barns, silos, milking parlors, and chemical laboratories. Our topography is rolling and our soils are variable. So, good plot land is scarce. Our facilities for finishing beef cattle are limited on this campus. Most of this work is done at one of the Research Stations.

We have a total of 13 Research Stations or Research Laboratories at strategic locations within the State and on eight of these we do research on forages or livestock or both. At three of these Stations the research is limited to crops and at a fourth the only form of livestock is hogs. One Station, Front Royal, is devoted mainly to beef cattle breeding. At Steeles Tavern and at Bell Glade, we do research on forage crops and on nutrition of beef cattle and sheep. The Station at Middleburg is the headquarters for our most comprehensive forage evaluation studies. We have both beef cattle and dairy cattle at this Station. The cows are used to evaluate the forages. The Departments of Animal Science and Dairy Science participate in planning the research and evaluating the results. One member of the professional staff holds a joint appointment in the Departments of Agronomy and Dairy Science. We have plans to provide a similar appointment in Animal Science and Agronomy for another man.

As we look to the future, I hope that we can evaluate the need for developing programs on the effects of controlled environments on nutritive value of forages and on nutritional requirements of livestock and on the efficiency of feed utilization. I would also like to review the need for research on reducing labor requirements for livestock enterprises. Our facilities for research in these areas are inadequate or nonexistent. If the staff decides that there are areas into which we should expand, we will have to find a way to finance the facilities that will be needed. This, too, will be a team effort.

Business Meeting - Chairman Anthony, Presiding

A business meeting of the Southern Pasture and Forage Crop Improvement Conference was called to order June 14, 1966, at 11:30 a.m. by Chairman W. B. Anthony. Present officers of Southern Pasture and Forage Crop Improvement Conference proper and of S-45 Technical Committee, Southern Forage Breeders Group, and Southern Forage Physiology and Ecology Work Group, all constituting the Executive Council of Southern Pasture and Forage Crop Improvement Conference were reviewed. Newly elected chairmen of S-45, Southern Forage Breeders Group, and Southern Forage Physiology and Ecology Group are John E. Moore of Florida, Stanley C. Schank of Florida, and Henry A. Fribourg of Tennessee, respectively. Chairman Anthony appointed a Nominations Committee of Roy Blaser (Chairman), Charlie Browning, and Dave Timothy for Chairman Elect-Elect of Southern Pasture and Forage Crop Improvement Conference, and a Resolutions Committee of Jack Harlan (Chairman), Clarence Hanson, and Robert Buckner for the present meeting of Southern Pasture and Forage Crop Improvement Conference.

R. H. Brown of Virginia Polytechnic Institute announced plans and instructions for the banquet in the evening at Mountain Lake Motel. Information and instructions on the Research Tour of the afternoon were given by J. F. Shoulders of Virginia Polytechnic Institute. The meeting was adjourned at 12: p.m. by Chairman Anthony.

Wednesday - June 15 - Morning
ANIMAL SCIENCE INTEREST GROUP
Dairy Auditorium - Saunders Hall
William Chalupa, Clemson University, Presiding

VOLUNTARY FOOD INTAKE IN RUMINANTS

Problems Associated with Measurement of Voluntary Intake - John E. Moore

Voluntary feed intake by ruminants is an important measurement in research on forage nutritive value and on the physiological aspects of hunger and satiety. The interest in these subjects is indicated by the number of recent symposia and review articles (2, 7, 11, 14, 17, 19, 25, 26, 28, 32, 33).

Researchers engaged in pasture and forage research recognize that voluntary intake may be the most important biological criterion of forage nutritive value, except for actual animal performance. The Nutritive Value Index for forages proposed by Crampton, et al. (10), includes a voluntary intake component. Reid (25) showed that changing the diet from forage of the lowest quality to that of the highest quality would result in a 36% increase in the Total Digestible Nutrient content of the diet and a 250% increase in voluntary intake.

A Regional Research Project in each of the four Regions is concerned with developing improved schemes of predicting forage nutritive value from characteristics of the forage as determined by chemical or physical methods. Reid (25) emphasized that a useful forage testing program must permit predictions of forage intake with sufficient accuracy that supplemental feed may be properly rationed. The development of the necessary prediction equations requires measurement of the intake of the forage as well as the laboratory characterization. The measures of intake must be highly accurate if the prediction equations are to have wide application.

It is the purpose of this paper to discuss several problems which are encountered in intake measurement and the various approaches to solving these problems that have been taken by forage researchers. In this discussion a "problem" refers to a decision that must be made by the researcher in the planning of an intake experiment. The literature indicates that there are many problems and many approaches to solving these problems.

In order to determine the frequency of use of the different methods currently employed in obtaining in vivo forage voluntary intake and nutrient digestibility data, the Technical Committee for Southern Regional Project S-45 authorized a survey of forage researchers. Questionnaires

were sent to 133 researchers, of which 49 returned completed forms. A summary was prepared and is now available.[1] The answers given to only a few of the questions will be discussed, but these will illustrate the variety of methods used to solve some of the problems associated with intake measurement.

Problems Associated with Hand-Feeding Studies

Measuring the intake of hand-fed animals involves direct concepts and procedures. Yet there are many problems which must be carefully solved in order to reduce the errors and variations which can contribute to inaccurate and imprecise intake values.

Problems in measuring the intake of one animal on one day. It is necessary to objectively determine how daily "*ad libitum*" or "voluntary" intake values are to be obtained. Blaxter, et al. (3), described a sequential scheme whereby the daily offering to an individual was 115% of the average consumption of the previous 2 days. The S-45 Survey showed quantities offered ranging from 102-130% of consumption with 17 of 37 researchers reporting 110%. The amount offered must not be decreased without careful judgment since transient, or one-day, depressions of intake have been encountered (3, 22, 30).

Problems in measuring the true intake by one animal. Several management factors may affect the voluntary consumption of forage. Any disturbance or excitement could alter intake. If digestion trials are also conducted, the animals may be placed in metabolism stalls or fitted with canvas bags in order to collect feces. It has been suggested that these factors will alter intake, but recent studies with sheep have shown no effect of confinement (13), metabolism rack (17) or fecal collection bags (22) on voluntary forage intake. The S-45 Survey showed that only 5 of 46 researchers reported using group-feeding in forage nutritive value studies, while 19 reported conducting digestion and intake trials simultaneously. Of 38 who make total fecal collections, 18 utilized fecal collection bags.

An adequate preliminary period is essential. Blaxter, et al. (3), suggested a minimum of 12 days. The S-45 Survey showed that from 1-30 days were used, with 22 of 32 researchers reporting from 5-14 days.

A true intake value for one animal is the average of intakes measured over several days. Blaxter, et al. (3), suggested that a 15-day measurement period be used to reduce the variability. The S-45 Survey showed the use of periods of 5-365 days. Of 36 who reported 30 days or less, 26 reported from 7-14 days with 10 reporting more than 14 days. The measurement period must be of sufficient duration that the effect of a transient depression is minimized.

[1] Summary: Survey of Forage Voluntary Intake and Nutrient Digestibility Methods, Technical Committee, Regional Research Project S-45, available from: John E. Moore, Nutrition Lab., Univ. of Florida, Gainesville, 32601.

Problems in Estimating the Finite Intake Value. The term, finite intake value, is used here in reference to an intake mean which has defined limits of accuracy and precision in terms of the width of the confidence interval and the standard deviation. The determination of the finite intake value to be assigned a forage is a statistical problem involving, in part, the number of animal observations per forage. Intake values are more variable than digestion coefficients (1). Heaney, et al. (15), summarized 441 determinations with sheep involving 2,427 individual animal/period measurements and found a between-animal coefficient of variation of 16.4%. Blaxter and Wilson (4) and Blaxter, et al. (3), reported coefficients of variation of 7.5% of the mean with steers and 13% with sheep. The variability among animals in grazing studies is of similar magnitude (12). The magnitude of animal variation is useful in determining the number of animals required to estimate the mean (6, 15, 30). The S-45 Survey showed the use of from 2-20 animal observations per forage. Of 37 replies, 11 reported using 4 observations and 18 reported the use of 4 or more observations.

The statistical design may also contribute to the accuracy of the finite intake value. If changeover designs are used, both animal variability and period effects may be evaluated. The S-45 Survey showed that 28 researchers used Latin squares, 13 switchback, 21 randomized block and 18 completely randomized. These answers applied to both intake and digestion trials and many researchers used more than one design.

Blaxter, et al. (3), reported significant differences in intake between the same animal at different times, illustrating a lack of repeatability. This problem has apparently received little direct attention. The S-45 Survey showed that 11 of 37 researchers rerandomized animals after a trial was complete and realloted them to the same forages.

Several different units of expression of voluntary intake data were reported by researchers in reply to the S-45 Survey: 18 corrected intake for body weight and 24 for metabolic weight ($W^{0.75}$ or $W^{0.73}$) while 4 made no animal weight correction. One researcher reported that efforts were being made to determine the proper exponent of body weight to be used. Holmes, et al. (16) found that exponents of body weight of 0.43, 0.62 and 0.73 all have applicability with different ages and weights. We have observed lower coefficients of variation between animals using $W^{1.0}$ than $W^{0.75}$ with steers ranging in weight from 220 to 515 kg (23).

Additional Problems Associated with Grazing Studies

Variations in Quantity of Forage Available. The intake of pasture may be influenced by the quantity of forage available to the animal (12). The quantity of pasture forage available at any one time is the net result of the rate of growth of the plant, the rate of removal by the grazing animal and the degree of wastage by trampling, fouling with excreta and selection (12). The rate of removal and degree of wastage are determined in part, by the stocking practice and grazing system. The S-45 Survey showed that 11 researchers used the put and take stocking practice while 10 used a constant rate. Four who used the put and take practice adjusted the stocking rate on the basis of available forage. Fifteen researchers used a continuous grazing system while 9 used a rotational system. Fifteen measured available forage while 8 did not. Van Dyne and Meyer (30) reported an inverse relationship between available range herbage and intake by cattle.

Problems Associated with the Indirect Estimation of Intake. All measures of pasture forage intake must be indirect. The animal indicator methods are considered more reliable than agronomic difference methods (6, 20). In general, the equation used to estimate intake by the grazing animal is as follows:

$$I = \frac{E \times 100}{100-D}$$

where: I = Intake of DM/24 hours
E = Excretion of DM/24 hours
D = Digestion coefficient of DM

Fecal excretion may be measured directly by the use of fecal collection bags, although this approach is laborious and expensive (12) and may not be used for long periods (5). Live weight gains may be reduced through use of the bags but intake and nutrient digestibility may not be affected (9). It has been suggested that the bags may also influence grazing behavior (12). The alternative is the indirect technique using an inert reference substance such as chromic oxide (Cr_2O_3). Animals are dosed daily with a known quantity and fecal samples are obtained rectally (grab samples). Analysis of the feces for Cr_2O_3 and dry matter permits calculation of the quantity of dry matter excreted. Assumptions are made that 100% of the Cr_2O_3 dose will be excreted daily, and that the feces aliquot analyzed is representative of the total. Neither assumption has proved to be reliable in practice, and many attempts have been made to improve the technique (5, 6, 9, 12, 24, 29). Putnam[2] conducted a survey on the use of Cr_2O_3 which illustrated the wide variety of techniques in use. The S-45 Survey showed that 13 researchers used total fecal collections and 13 used the indirect technique.

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[2] Survey of the use of chromic oxide in ruminant research. Available from: P. A. Putnam, AHRD, ARS, USDA, Beltsville, Maryland.

Determination of digestion coefficients under grazing conditions must be indirect, either by use of fecal index or ration techniques. In the fecal index technique, feces are analyzed for an indicator substance and digestion coefficients calculated by use of regression equations. Fecal nitrogen (18) and chromogen (27) have been used with success. Regression equations must be established for each set of conditions, unless only relative intake values are desired (5, 9, 21). The ratio technique requires a knowledge of the ratio of nutrient to indicator in both forage and feces.

The difference in these ratios can be used to calculate digestion coefficients. The indicator used must be a component of the forage. Assumptions are made that the indicator is indigestible and completely recoverable and, if grab samples are used, both indicator and undigested nutrient are excreted uniformly. The S-45 Survey showed that 8 researchers used a fecal index technique (6 nitrogen and 6 chromogen) and 13 used a ratio technique (8 lignin and 5 chromogen).

With the ratio technique it is necessary to obtain a sample of the pasture for chemical analysis. The methods used have been reviewed recently by Cook (8). The S-45 Survey showed the following frequencies of use: 8 hand-plucking, 12 clipping, 11 esophageal fistula and 4 rumen fistula. Because of the selectivity of the grazing animal (11), fistulated animals should be quite useful in obtaining pasture samples. Esophageal fistula techniques have been reviewed (31,33).

Summary

The measurement of voluntary intake in hand-feeding studies involves direct concepts and procedures. However, many problems are encountered in determining the procedures to be used for the daily measurement of intake, for measurement of the true intake of one animal and for estimating the finite intake value. Among the most important problems are determining the proper length of the intake measurement period and the proper number of animal observations per forage. When intake of pasture or range forage by a grazing animal is to be determined, there are additional problems, such as that of determining the stocking practice and grazing system to be used. The most perplexing problems in grazing studies are those associated with techniques for estimating intake, particularly the measurement of fecal excretion and digestion coefficients.

The literature and a survey of forage researchers have clearly shown that there are many variations in approaches used to solve the problems associated with intake measurement. There are no standard procedures for derermining intake as there are for determining laboratory forage characteristics. The development of equations to predict intake from laboratory forage characteristics requires highly accurate intake values. Every effort should be made by each researcher to select experimental procedures which give intake values of the highest accuracy and precision under his own conditions. The question of recommending a set of procedural guidelines or minimums to be adopted by forage

evaluation researchers at different laboratories remains open at this time but it is deserving of careful consideration.

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C Metabolic Events Associated with Hunger and Satiety - Don R. Jacobson

Very recently, much interest has developed in the area of voluntary feed or forage intake in ruminants. This is certainly justifiable since it is generally accepted (a) that there are very small differences in the utilization of energy among animals of a given species for a given function and (b) that increased performance and increased efficiency of performance can only come about through increased voluntary feed (energy and nutrient) intake. Just to make all the known requirements for nutrients and energy available in a dietary formula is not enough to warrant top performance and efficiency, as voluntary intake is highly variable, particularly in ruminants. Hence there is a current intense interest among nutritionists in getting at the factors that regulate or control voluntary intake.

Fundamentally, there is much good evidence which shows that food intake regulation is mediated by the hypothalamus (1). Furthermore, it has been amply demonstrated that there is a "feeding" center in the lateral hypothalamus which acts continuously and provides the basic urge to eat and a "satiety" center in the medial hypothalamus which exerts an inhibitory effect upon the "feeding" center causing the animal to stop eating intermittently. The fundamental question remaining then regards the source and nature of the stimulus upon the feeding and satiety centers of the hypothalamus. Many theories, hypotheses, or proposals have been put forth to explain the sources of the impulses. Two of these, the thermostatic and chemostatic theories on the regulation of voluntary intake, will be discussed here.

Thermostatic Regulation of Food Intake

The hypothesis for the thermostatic regulation of feed intake (4,5,22) is based upon the known existence of thermoreceptors in the hypothalamus (16) and that one of the certain responses to eating is heat production, often referred to as heat increment or the specific dynamic action (SDA). It says that an animal will stop eating when sufficient SDA causes the temperature of the CNS to rise sufficiently. Two kinds of observations have been presented to support the hypothesis. First, either fat carbohydrate or protein added to mixed diets of rats caused a quite different intake from the previous intake. Computation of the SDA of the ingested calories on all diets revealed a remarkable agreement suggesting that the SDA may exert more effect on intake than caloric value, weight or volume, or nutrient composition. If SDA is a factor, increased SDA could reduce intake when cooling power is limited, but could increase intake where cooling power is not a limiting factor (15). Second, local cooling of the preoptic heat loss center of the hypothalamus of goats induced eating shortly after a meal whereas, warming inhibited eating in the same goat when it was hungry (2). The question is: Do ruminants on different diets and intake eat to a constant SDA or to certain elevated temperature of the CNS in a given environment.

Using the heat increment values listed in Morrison's text (19) and by taking 30 lbs. of timothy hay containing 9.4 therms of heat increment as a base, equivalent amounts of ground corn and wheat straw yielding equal heat increments would be 18.0 and 19.9 respectively. Net energy consumption would be 12.9, 14.9 and 2.0 therms respectively. A perusal of our data on intake over a variety of diets though different environmental temperatures suggest that cows do not consume feed to a constant total heat increment. Nevertheless, the Texas work has shown that cows will eat more feed net energy when offered rations of lower heat increment and other work has shown that cows in a cold environment eat more than those in a moderate environment. Dietary deficiencies are known to raise the heat increment and this may be a reason for the associated reduced feed intakes. Kennedy (13,14) indicates that if this theory held true, heat released during muscular exercise should cause reduction in food consumption. Also, the addition of thyroprotein to the ration results in increased food intake whereas a decreased intake by increasing the SDA of the ration would be expected. It seems reasonable that if there is thermostatic regulation of appetite (3) that it would come into play after the compensatory mechanisms for thermo-regulation have been stressed so as to affect the temperature of the blood circulating through the CNS. If this be the case, consumption to a total heat increment would be variable with environmental temperature. Finally, thermostatic regulation of feed intake has not been shown to function under physiological conditions. In our laboratory, we have toyed with the idea of measuring feed intake in a constant temperature with induced changes in CNS blood temperatures by cooling or warming the arterial supply and compensatory changes of the venous return. Of course, we would first want to monitor physiological changes in CNS blood temperature associated with eating and with different levels of intake.

Chemostatic Regulation of Food Intake

To the author, this is the most exciting possibility for explaining feed intake. Ever since Lavsier said on the basis of his findings that life is a chemical function, scientists have been increasingly relating living processes to chemical reactions. Certainly there are many chemical changes that occur following the consumption of food. Some of the chemical changes that may affect intake are discussed.

The lipostatic regulation of appetite has been suggested particularly for long-time regulation (7,13). It is based on the fact that animals mobilize each day a quantity of fat proportional to the total fat of the body, and the greater the amount of fat being mobilized the greater the inhibition on the feeding center.

Mellinkoff (18) correlated appetite with serum amino acids and blood sugar concentration in human subjects given hydrolized protein and glucose. He suggested a reciprocal relationship between the serum

amino acid concentrations and appetite and found no change in electric action of hypothalamic centers in animals after intravenous infusion of protein hydrolysate. In the classical experiment of Rose it became clear that deficiency of one amino acid would cause a serious reduction in appetite, and Combs (8) more recently has reported the depressing effect on appetite from either a single amino acid deficiency or excess.

Amphethemine is the most extensively prescribed pharmacological preparation given to depress appetite. This drug appears to have a stimulatory effect upon the satiety center as indicated by an increase in frequency and amplitude of recorded activity of the medial hypothalamus (6).

Meyer (17) in the early 1950's introduced the concept of chemical control of feed intake through the glucostatic theory. It was shown that in normal and diabetic animals, decreased gluclose availability or utilization correlated well with increased food intake. He further points out that absolute blood glucose levels by themselves do not give a measure of availability. The "hunger" state is one in which glucose uptake tends toward zero whereas in the "satiety" state there is an appreciable glucose uptake. It has further been demonstrated (10) that uptake of p^{32} by the hypothalamus is greater in the region of the feeding mechanism than in others. Thus there is evidence that glucose plays an important role in the monogastric animal's appetite regulation. In following up on this concept, we administered intravenously for 8 hours a day, 3 consecutive days a number of major energy source metabolites of the ruminant animal (9). Glucose, at 25% of the daily energy requirement for maintenance had no effect on voluntary feed intake even though blood glucose levels were maintained at slightly over 100 milligrams per cent (approximately 2½ times normal). Neither did butyric acid, valeric, caproic acid, or lactic acid at the 6½% level have any effect on voluntary feed intake. On the other hand, acetic acid, sodium acetate, and propionic acid at the 12.5 level had a very significant($P < .005$) effect on voluntary feed intake.

In another series of trials (12) a total of 16 dairy steers were employed to study the effect of continuous infusion of either acetic or propionic acid upon voluntary feed intake and blood and rumen levels of volatile fatty acids. Infusions were in 3 liters volume for 8 hours duration for 3 consectuive days to supply from 5 to 10% of digestible energy requirement. Control animals received saline. The infusion of acetate reduced significantly ($P < 0.01$) the voluntary feed intake during the infusion as well as during recovery periods. Infusion of acetate or propionate caused an increase in the blood level of the respective metabolite. Acetate infusion led to an increase in the blood butyrate and propionate in some instances. Propionate infusion reduced blood acetate significantly, but had no effect on blood butyrate. There was a significant multiple correlation between blood levels of acetic, propionic, and butyric acids and level of infusion and voluntary feed intake. The data suggest that the short term mechanism of feed intake regulation is not dependent upon one metabolite only, but it is a complex one. There is

evidence that an adaptation mechanism operates during infusion, for many animals' blood levels increase significantly during the first 3-day infusion, to be followed by a relatively small increase in blood levels when either acetate or propionate were employed during the second 3-day infusion. The 0 hour levels of metabolites employed gave a sizable relationship with voluntary feed intake. Here again is evidence that these metabolites at normal as well as infusion levels, may have an influence on voluntary feed intake. In general, much of the variation in voluntary feed intake was accounted for by the blood levels of metabolites and by level of infusion. Simkins, Suttie, and Baumgardt (20,21) have also reported that blood and rumen VFA increase after feeding and that satisation occurred at maximum levels. In their infusion studies, butyrate as well as acetate and propionate reduced voluntary intake.

In two of the more recent experiments related to voluntary feed intake, 24 lactating cows (half Holstein and half Jersey) were placed on a diet of either high population corn silage to which had been added soybean hulls or standard population well eared corn silage as the only roughage and a concentrate mix to supply 50% of the energy requirement. Voluntary roughage intake was measured individually.

In the 1963 trial average milk production, and dry matter intake were significantly increased for the cows on the high population corn silage to which had been added 400 lbs. soybean hulls per ton. The increase in milk production was truly outstanding and could not be accounted for on the basis of established nutrient requirements. In a further attempt to interpret the increased dry matter intake and milk production associated with consumption of high population corn and soybean hull silage, another trial was conducted. Again, interpretation of these results is very difficult, but this much is clear: 1) The cow does not eat just to satisfy her energy requirement; 2) Differences in body weight could not account for the differences in voluntary dry matter intake; 3) Dry matter digestibility was greater instead of lower for the diet of lower voluntary consumption; 4) Increased voluntary roughage intake was associated with increased milk production and increased weight gain; 5) The efficiency of use of digestible energy above maintenance and body weight gain for milk production was the same even though energy intake was quite different; 6) To increase milk production in any given group of cows, an increased amount of energy must be consumed; and an increase in body weight must be expected. Why the cows consume more of the high population corn-soybean hull silage and how the principle involved may be employed for greater consumption of other feedstuffs remains a mystery. The increased blood acetate levels approximately 3 to 4 hours after feeding may well be the result of the increased fermentation and production of acetic acid associated with the increased intake. This is not interpreted to mean that the volatile fatty acids do not play a role in the control of voluntary feed intake, but rather that much more information on the diurnal patterns of rumen VFA levels and production and portal and arterial as well as jugular venous blood levels is needed.

Also, blood levels and production of the amino acids and intermediate metabolites should be considered.

Much more work needs to be done before a cause and effect of metabolic events on voluntary food intake can be clearly understood and established.

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Forage Intake in Relation to Chemical Composition and Digestibility: Some New Concepts -

J. P. Van Soest

Recent research regarding factors affecting the voluntary intake of forages has tended to suggest that gastrointestinal fill may not be as important as was first suggested (Conrad, 1966, Jacobson, 1966). It has not been possible to find a significant relationship between intake and digestibility or between forage cell-wall fiber content and voluntary intake where the cell-wall content is less than 55-60 percent (Van Soest, 1965). A negative relationship between voluntary intake and digestibility has been postulated for highly digestible feeds (Conrad, 1966) and a positive relationship for poor-quality feeds (Van Soest 1965).

The failure to demonstrate a relationship in high-quality feeds between intake and forage volume, as represented by cell-wall content, may mean that fill is not large enough to be a limiting factor under these conditions or that in the presence of other complicating factors it may be difficult to measure. This presents an important problem because many feeds in this country and elsewhere are the higher quality ones. Thus, under practical feeding conditions we do not really understand the control of intake. Another problem also exists in silages where intake is almost always less than that expected from cell-wall content (Thomas et al. 1961, Waldo et al. 1966).

This situation has caused several of us at Beltsville to inquire into the basic understanding of the fill and rate of passage concept. One may search for other factors that affect intake, but an understanding of the control of flow of digesta through the digestive tract is basic to our complete understanding of intake. The present discussion will center on the relationship between the chemical and physical composition of the ration in relation to that of the feces and the consequent problems raised regarding rates of digestion and passage.

Composition of the fecal dry matter.--The feces of animals do contain non-cell-wall material, but this component does not have any identity with the non-cell-wall matter in the forage fed animal (Jarrige 1965). The non-cell-wall matter is readily digested. Average digestibility of this latter fraction is 98 percent, with little variation over a wide variety of forages and digestibilities (Van Soest and Moore, 1965).

Endogenous and bacterial fractions of the feces.--The fecal non-cell-wall matter is composed of animal residues and bacterial matter from the digestive process. The bacterial residue appears to comprise the larger part of the non-cell-wall matter and is composed of bacterial protein resistant to proteolytic enzymes (Van Soest et al. 1966, Virtanen, 1965). One would expect the bacterial residue to be related to the extent of overall fermentation, and the amount of bacterial and endogenous fecal matter is highly related to the level of intake, as shown in Figure 1. In the past, theory has considered endogenous excretion to be constant, but the plot suggests a curvilinear increase at high levels of intake. At the highest level of intake, excretion amounts to about 4 kg. dry matter per

day. It is an open question as to whether this quantity is critical in affecting intake. Basically, the most important issue is whether the bacterial and endogenous excretion forms a constant ratio to intake, because when this fraction is expressed as a percentage of intake, it is arithmetically subtractive from true digestibility to give apparent digestibility, as shown in Table 1.

When this percentage is plotted with level of maintenance, using the samples from Figure 1, the result (shown in Figure 2) is a division of the data into two groups. Examination of Figure 2 shows that lactating cows, which will consume forage at a higher level than dry cows, significantly increase bacterial and endogenous excretion with level of maintenance. It follows that apparent digestibility must decline because of this increase.

The pattern exhibited by dry cows and heifers is different, the trend being in the opposite direction. While the regression lacks statistical significance, this decline does have some meaning, in that in very poor forages of low digestibility, in which the intake does not reach maintenance, bacterial and endogenous excretion as a percentage of intake tends to increase. This effect might be demonstrated by plotting the endogenous and bacterial excretion against apparent digestibility (not shown), where an insignificant negative correlation has been obtained with cattle (Van Soest et al. 1966).

However, if bacterial and endogenous excretion per unit of maintenance is plotted against apparent digestibility, high significance results, as shown in Figure 3. This suggests that the intake of digestible energy has an important effect in the generation of bacterial residues in the digestive tract. It also might suggest that poor-quality coarse roughages may induce more sloughing on the part of the animal.

One wonders which scale, dry matter or a measure of metabolizable energy such as maintenance, is more appropriate for measuring intake. It will require more dry-matter intake to achieve the same level of maintenance with a forage of low digestibility as compared to a higher one.

To summarize, the relationship between the non-cell-wall matter, voluntary intake, and digestibility, it should be pointed out that forage non-cell-wall material almost wholly disappears in the digestive tract, and that the fecal non-cell-wall matter is composed of bacterial and endogenous excretions. The latter are not at all constant with type of animal, digestibility, or as a percentage of intake.

It should be further pointed out that anything increasing endogenous excretion relative to intake will cause an apparent decline in apparent dry-matter digestibility without any change in the true digestibility of the forage. These comments would be pertinent to any discussion of the decline in digestibility with increased level of intake.

Contribution of the cell wall fraction.--To pass on to the insoluble and intractable parts of forage, there are two measurement problems that must be faced. These are the volume occupied by the hydrated mass of forage in the tract and the length of time such hydrated fiber remains in the rumen or other part of the tract. As regards the first problem, it should be pointed out that the forage residue responsible for the volume occupied by plant tissue is the cell wall structure. It should be further noted that the contents of the cells might be removed and even portions of the wall might be digested and yet the volume of the structure would be little changed. However, destructive grinding and crushing should have quite a different effect.

As regards the other problem, that of time in the digestive tract, disappearance occurs in two ways, by digestion and passage. Reduction of intake is also a relief from fill pressure. Faster passage should be associated with decreased fiber digestibility, as in the case of finely ground forages. If passage could not be increased, dietary increase in bulk could only be relieved by reduced intake. If the animal has any control of the rate of passage, this would allow accommodation to an increase in the volume of intake.

A fascinating aspect of the fiber digestion was discovered by accident. In an attempt to prepare cell-wall material of high lignin content, fecal cell-wall material was prepared in kg quantity by water-washing on a 20 mesh screen. Surprisingly the lignin content of such material was only slightly higher than that of the forage cell-wall material, indicating only slight digestibility of this large particulate fraction. In an attempt to recover the more thoroughly digested and lignin-bearing particles, the neutral-detergent fiber has been scaled up to handle as much as 100 gm quantities of forage and feces. Such cell-wall preparations are carefully dried with acetone, hexane and then air to prevent clumping of particles. The mass is then sifted on standard screens using a mechanical shaker. The weight distribution of particle sizes is recorded. The chemical composition of the differently sized fractions have also been examined.

Preliminary results from such studies show that the lignin content of fecal cell-wall particles decreases with increasing fecal particle size, while those of the feed tend to vary in an opposite manner, as shown in Figure 4. It is possible that the less mature parts of alfalfa--i.e., leaves and fine stems--may contribute more to the finer fractions upon grinding. However, this will not explain the amounts and composition of the fecal fines. Estimated digestibilities by lignin ratio show that the fecal fines passing 100 mesh (.15 mm) have undergone up to twice the degree of digestion that the coarsest particles have. Furthermore, the fines are of such a quantity that they cannot be accounted for by the amount of fines in the forage, as shown in Table 2. As expected, ground and pelleted hay shows a smaller shift in particle sizes from feed to feces than does chopped hay. But it is interesting that relatively finely ground and pelleted hay nevertheless undergoes an appreciable particle size reduction on passage through the animal.

The average particle size in feces from pellet-fed animals is larger than that from chopped hay. Distributions of size are shown in Figure 5, which compares concentrate supplemented hay, pellets, chopped hay, and silage, with relative particle size significantly decreasing in that order (Smith et al. 1965). There is a strong inference that the efficiency of the particle-size reducing mechanism--preseumably rumination--is much affected by the form of the ration and an increase in the size of fecal particle probably indicates a faster rate of passage (Balch and Campling 1965). To carry the matter further, the effect of level of intake on fecal particle size may be seen in Figure 6, and is as would be expected to increase the fecal particle size with level of intake.

So it would appear that providing a stimulus for intake--that is, lactation--the cow will increase passage rate and intake in order to meet the energy demand. Does fecal particle size increase because the cow no longer ruminates equally the larger mass of ingesta? Does this mean that rumen fill and cell-wall bulk of the ration are not important in limiting intake, but that the animal just passes it on faster when the demand is greater? High producing dairy cows are often in negative energy balance, and will usually consume more energy when hay is supplemented with concentrate. What then limits intake in high-producing animals? Certainly not energy!

Reserving answers for later theoretical discussion, it should be pointed out that the data raise many questions. Only alfalfa has been examined in detail, and grasses are presently being examined in regard to forage and fecal particle sizes. The data make us very skeptical about the interpretation and the manner in which some passage data are obtained. The stained-particle technique, as frequently used, measures only the largest particles appearing in the feces, and they are the ones which have undergone the least representative digestion.

An important aspect of the effect of particle size is that of rate of digestion. Published data would indicate fine particles are more rapidly digested than coarser ones (Dehority et al. 1962, Baumgardt and Hi Kon Oh, 1964). Also it appears that fine particles pass through the digestive tract faster than larger ones (Huston and Ellis 1965, Pearce 1963). It should be apparent that fines arising from larger particles upon rumination should appear at a relatively later time than those of the same size initially present in the forage. In addition to the rates of digestion and passage, a third rate must be added--that of particle size reduction--which is required for an adequate model of what happens in the digestive tract of ruminants. As has been implied, the rate of size reduction must vary with conditions.

Note that our data show an increase of fecal particle size with pelleting of the forage. Does probable reduced rumination on a pelleted ration mean a lowered rate of particle size reduction? Such an interpretation would fit the data.

If one considers the paradox presented in a recent paper of Campling (1966), where increased level of concentrate is associated with unchanged cellulytic rate, decreased rate of passage of fiber, and decreased fiber digestibility, a resolution might be found in a reduced rate of particle-size reduction due to less overall rumination. It should be noted that addition of concentrate increased particle-size in the feces (Figure 5). One must consider that the rate of passage of a given particle size may vary depending on the formation of a mat in the rumen. The latter may disappear with fine grinding and pelleting. One must also consider that the probability of passage of a given particle size will be related to its concentration in the rumen.

Another perspective may be obtained by plotting the lignin in the cell walls of the forage against those of the feces. While the lignin content of forage cell walls is uniformly associated with declining digestibility of cell walls, it may be seen in Figure 7 that the lignin content of fecal cell walls declines with that of the forage in grasses and increases in legumes. The grasses at the bottom of the curve in Figure 7 are the most mature and have cell-wall contents on the order of 70% of the dry matter. One observes that their digestibility is less than one would expect from the regression of cell-wall digestibility on lignin. On the other hand, a few very early cut grasses have low content of cell walls and higher digestibilities than would be anticipated. The suggestion is that the cell walls of early grasses and most legumes are sufficiently low in volume and quantity in the rumen so that there is less pressure for their passage. Fiber can remain for a longer time and be digested to a higher lignin content.

How does one synthesize all of the foregoing into a general working hypothesis to account for digestibility-voluntary intake-forage composition relationships? One should expect in case of a higher intake of cell-wall contents a greater pressure towards passage of fiber particles. This is observed in that a larger particle size in the feces results. The back pressure from this could limit intake in forages of sufficiently high cell-wall content. This general relationship has also been found (Van Soest 1965, Ingalls et al. 1965). Also, in the case of the forages of lower cell-wall content, fiber may remain in the tract to be digested to a greater extent because fiber volume is small in relation to the overall forage consumed. This is seen in very immature grasses and perhaps in high-quality legumes as well. The effects of grinding or pelleting forage will destroy the volume-time occupying capacity of a forage. This would lead one to expect--if fill is important--greater voluntary intake. The effect in poorer quality forages with higher cell-wall content should be greater than in higher quality forages and legumes of low cell-wall content (Moore, 1964). One will expect a greater depression in dry matter intake of grasses and particularly of late cut grasses of the highest cell-wall content. This has also been observed in ryegrass (Blaxter 1962).

From the above one can build a circumstantial argument supporting the effect of fill on intake. One can detract from the argument by pointing out the shift in fecal particle size and probable increase in rate of passage with very high levels of intake. Yet a heavily milking cow still will not consume forage to meet energy demands. A resolution might be that some form of equilibrium exists between the desire to consume, the demand for energy, the distension in the tract, and the ability to adjust digestion to a faster rate of passage.

The original data relating cell-wall content to voluntary intake were obtained with sheep (Van Soest 1964) and heifers (Ingalls et al. 1965). These results did not show that cell-wall content of alfalfa had a significant effect on consumption. However, it might be wondered whether, if intake had been measured with lactating cows, the result might have been different. There should be a greater sensitivity to cell-wall volume at high levels of nutrition and production, and order of ranking forages can differ with animals in different physiological states, (Buchman and Hemken 1964).

In summary, it can be said that critical experiments have yet to be devised which will accurately assess the contribution of the various factors that regulate voluntary intake. Nevertheless, the following points can be made:

1. The relative balance of various factors affecting the digestibility and voluntary intake of forages is different for non-lacting and lactating animals.

2. Fill and the volume of a forage as represented by the cell walls may be critical at very high levels of intake achieved with lactating cows and be much less important at low levels of intake.

3. The pattern of endogenous and bacterial excretion is different for lactating and non-lactating cows.

4. The endogenous and bacterial excretion may vary with physiological state, level of intake and digestibility. At very high levels of intake with lactating cows, it may increase and be partly responsible for declines in apparent digestibility.

5. Other factors that can affect the extent of digestion are the rates of passage, rate of cell-wall particle breakdown, and rate of digestion.

6. The rates of passage, particle breakdown and digestion are interrelated and basic to a proper understanding of ruminant digestion. This knowledge is necessary before reliable predictions of nutritive value based on chemical and physical criteria can be made.

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TABLE 1. Summative Relationship Between True and Apparent Digestibility: Example of an alfalfa hay.

Constituent	Percent in Dry Matter	True Digestion Coefficient	Digestible Amount
Cell contents (neutral detergent soluble)	60	98	58.8
Cell-wall constituents	40	45	18.0
	Total (True digestibility)		76.8
	Endogenous and Bacterial matter (as percent of intake)		-12.9
		Apparent digestibility	63.9

TABLE 2. Comparison of particle-size distribution of cell walls in pelleted and chopped alfalfa and the corresponding feces.

Form	Particle Size	Cell walls fed	Cell walls in equivalent amount of feces		Discre-pance
			Actual	Theoretical 1/	
	MM	gm	gm	gm	gm
9.5 mm pellets (3/8 inch)	>1.19	6.4	0.6	2.2	-1.6
	0.6-1.19	30.8	10.7	20.6	-10.2
	0.3-0.6	27.0	19.7	16.5	+3.0
	0.15-0.3	23.0	15.7	11.3	+4.2
	<0.15	12.8	10.3	5.7	+4.6
	Total	100.0	57.0	57.0	0
37 mm chopped (1 1/2 inch)	>1.19	28.8	1.0	17.3	-16.3
	0.6-1.19	33.5	9.1	20.1	-11.0
	0.3-0.6	18.4	16.6	9.7	+6.9
	0.15-0.3	11.4	17.1	5.7	+11.4
	<0.15	7.9	12.2	3.2	+9.0
	Total	100.0	56.0	56.0	0

1/ Quantity expected if all fecal particles originated from the same size fraction in the forage. Values calculated on the basis of lignin ratio.

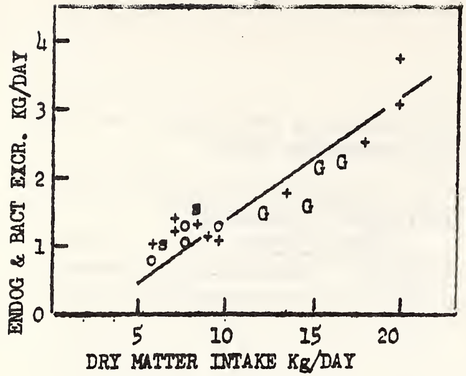

Figure 1.- Relationship between the dry matter intake and excretion of bacterial and endogenous matter in the feces of cattle. Regression equation: Y = 0.15 - 0.3, correlation +0.95**.

HAY - - - +
LF HAY & CONC- - G
RASS HAYS- - - - o
LFALFA SILAGE- - s

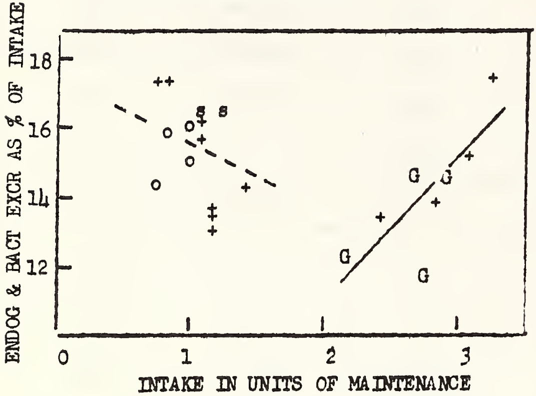

Figure 2.- Plane of nutrition and endogenous and bacterial excretion. Right group represents lactating cows: Y = 2.6 + 4.3 X, r = 0.77*. Left group represents dry cows and heifers: Y = 17.4 - 1.8 X, r = -.3, not significant.

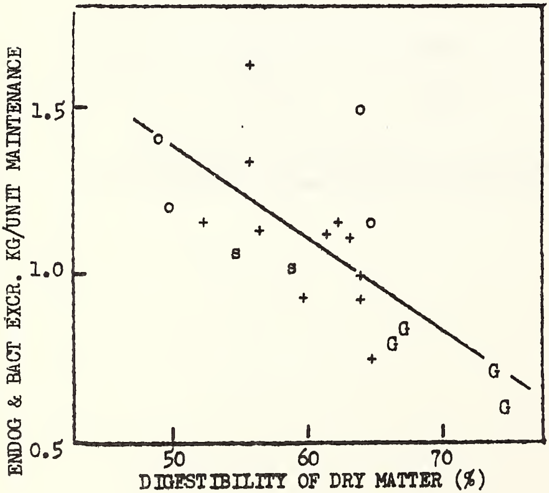

Figure 3.- Endogenous and bacterial excretion per unit of maintenance as related to digestibility. Y = 2.65 -.026X, r = -.68**.

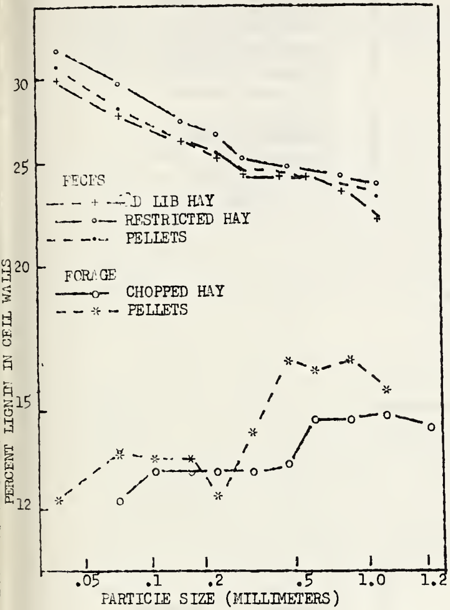

Figure 4.- Relationship betweenm the lignin contents of the cell walls of alfalfa fed in different forms and that of the feces in respect to particle size.

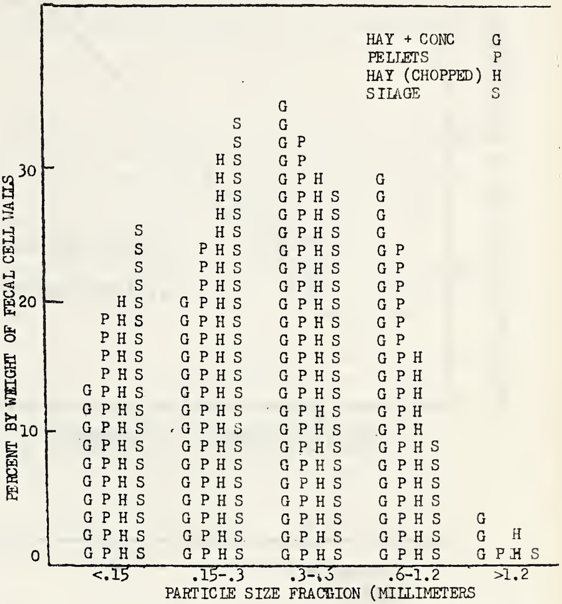

Figure 5.- Distribution in size of fecal particlés from four rations fed to cattle near maintenance. Silage, hay and pellets were made from alfalga. (data of Smith et al 1965)

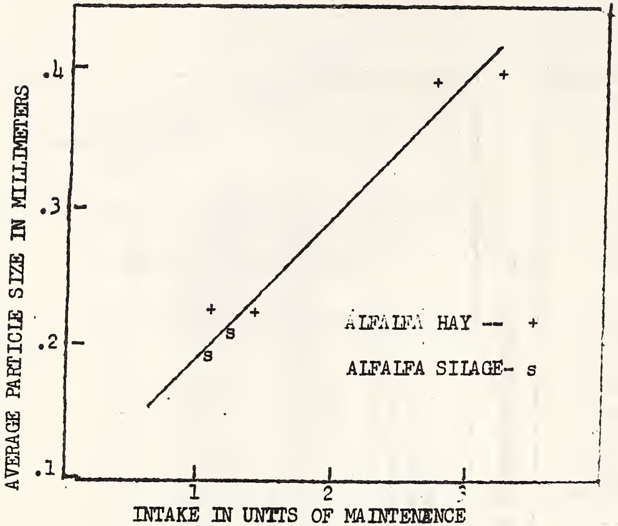

Figure 6.- Relationship between fecal particle size and intake. Highest levels of intake were obtained with lactating cows. Regression: Y = 0.1 + 0.10 X, r = +0.9**.

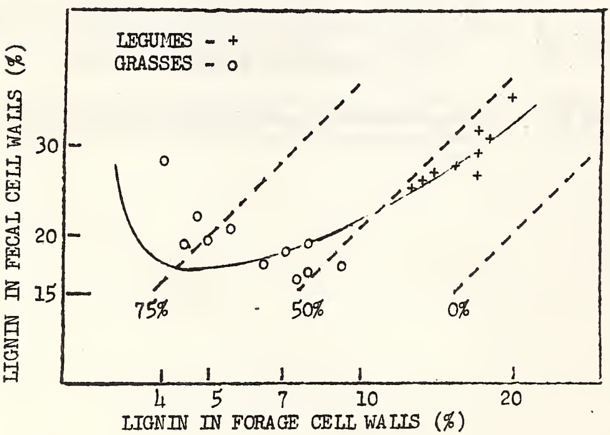

Figure 7.- Lignin contents of cell walls of forages and corresponding feces. Isoclines of 0, 50, and 75 percent digestibility shown as dashed lines. Solid curved line, the projection of the regression of cell wall digestibility on log lignin content of forage cell walls.

C Effects of Environmental Temperature and Ration Composition on Intake of Dry Matter and Energy -

Marvin E. Riewe

Hot weather affects cattle by making it more difficult for them to loose heat from their bodies. Heat stress on the animal body is caused by both external and internal factors. The animal body may gain heat from external sources such as the sun (solar radiation) or, when air temperature exceeds body temperature, from the air in the environment around the animal. Internal causes of increased body temperature are (1) heat production associated with digestion, (2) heat production associated with basal metabolism; (3) heat production associated with a productive function such as growth or milk production, and (4) activity such as the work of grazing or walking.

At air temperatures below 70°F, heat can be lost readily from the animal body by the process of radiation of heat to cooler surroundings or by conduction and convection of heat to the air. At air temperatures above 70°F, however, loss of heat by radiation and conduction and convection becomes slower and more of the body heat must be eliminated by evaporation. When the air temperature exceeds body temperature all excess body heat must be lost by evaporation. The amount of heat lost by evaporation is related to both the temperature and the humidity of the air. As the water vapor content of the air rises, the capacity of the air to absorb additional water vapor decreases. Therefore, with increasing environmental temperatures, humidity becomes increasingly important.

The heat associated with digestion of feeds is often called the heat increment of a feed or forage. The heat increment of a feed or forage varies with the kind and amount consumed. Heat derived from the digestion process is heat over which the animal body has little or no control. The heat that is derived from the energy required for the digestion of a given amount of nutrients is much greater, for example, from high fiber feeds or forages than lower fiber feeds. Additional heat associated with a productive function, such as growth, milk production or fattening, or associated with an activity such as the work of grazing or walking must also be dissipated.

The first response observed in cattle exposed to increasing air temperature is an increase in respiration rate. This allows for an increase in evaporative heat loss. A rise in air temperature also causes a rise in skin temperature, making it easier for heat to pass from the skin to the air. An increase in skin moisture, which can be evaporated, accompanies the rise in skin temperature. If these means of losing heat are inadequate to balance body heat gains, the temperature of the animal body rises(4).

That increasing temperature reduces feed intake of the ruminant animal has been demonstrated repeatedly (1,2,5). Further, the work of Leighton and Rupel (3,4), Stott and Moody (7) and Wayman, et al (5) clearly suggest that the magnitude of the effect of environmental temperature on feed intake is dependent upon the kind of ration being fed.

Because the heat stress on the animal body is caused by both external and internal factors, the effect of environmental temperature and kind of ration and the interaction of these on feed intake is important.

Two recent studies conducted by Texas A&M University at the Gulf Coast Pasture-Beef Cattle Research Station at Angleton shed some light on this question. In the first study, three rations varying widely in composition were fed in temperature controlled chambers to mature sheep at constant temperature levels of 55°, 70°, 85° and 100°F. Eight sheep were individually fed each ration at each temperature level. The composition of the rations is shown in Table 1. Ration 1 was a high concentrate ration containing 79% corn and 5% soybean oil meal. Ration 2 and 3 contained only 43% corn, with ration 2 containing 30% wood cellulose (Solka Floc), while ration 3 contained 30% ground polyethylene. Additional soybean meal was added to rations 2 and 3 so that all rations would be isonitrogenous.

Table 1. Ration Composition:

	Ration Composition(%)		
Ingredient	Ration 1 High Concentrate	Ration 2 Cellulose	Ration 3 Polyethylene
Ground corn	79.0	43.0	43.0
Cellulose (Solka Floc)		30.0	
Ground polyethylene			30.0
Dehydrated alfalfa	10.0	10.0	10.0
Soybean oil meal (50% protein)	5.0	11.0	11.0
Molasses	5.0	5.0	5.0
Salt	0.5	0.5	0.5
Defluorinated phosphorus	0.4	0.4	0.4
Vitamins and trace minerals	0.1	0.1	0.1

The daily dry matter intake of each ration at the various temperature levels are shown in Table 2. As temperatures increase from 55 to 85°F, daily dry matter intake, expressed as the percent of bodyweight, decreased similarly for all rations. Feed consumption was greatest for the polyethylene ration, intermediate for the cellulose ration and lowest for the high concentrate ration. However, at 100°F there was a sharp decline in intake of the cellulose ration while the decline in intake of the polyethylene ration was not quite so sharp and an even smaller decline with the high concentrate ration.

Table 2. Effect of environmental temperature on dry matter intake by sheep fed several grain rations.

		Temperature, ^{o}F			
Ration	DMD %	55	70	85	100
High Concentrate	87.1	3.52	2.92	2.59	1.94
Cellulose	73.0	4.23	3.66	3.41	1.71
Polyethylene	59.0	4.72	4.07	3.41	2.43

The digestibility of the rations was determined. The daily digestible dry matter intake, expressed as percent of body weight, is shown in Table 3. At temperature levels of 85^{o}F or less the digestible dry matter of the three rations was approximately equal. Although the digestible energy content in the polyethylene and cellulose rations was diluted, the sheep were apparently able to compensate for most of the energy dilution by eating more of the polyethylene or cellulose ration. However, at 100^{o}F both the dry matter intake and the digestible dry matter intake of the cellulose ration was lower than that for either of the other two rations and the digestible dry matter intake of the high concentrate ration was significantly greater than of the cellulose ration.

Table 3. Effect of environmental temperature on digestible dry matter intake by sheep fed several grain rations.

	Temperature ^{o}F			
Ration	55	70	85	100
High Concentrate	3.07	2.54	2.26	1.69
Cellulose	3.09	2.67	2.49	1.25
Polyethylene	2.79	2.40	2.16	1.43

Considering temperatures of 85^{o} and 100^{o}F, there was a significant temperature X ration interaction with respect to both dry matter intake and digestible dry matter intake. Temperature alone at all levels and ration alone each had a significant effect on dry matter and digestible dry matter intake.

A second experiment conducted at the Gulf Coast Pasture-Beef Cattle Research Station at Angleton involved only forages each fed to six sheep, at 60 and 90^{o}F. The five hays used are shown in Table 4, together with the chemical composition and apparent dry matter digestibility. The Gulf

ryegrass hay and the Sudax hay cut on June 29 were dryed with artificial heat. The other three hays were field cured. The ryegrass was cut while still in a vegetative stage. The Coastal bermuda was cut on July 20 following a 4-week growth period. The alfalfa was a May cutting. The Sudax cut in June had been planted on May 27 and was cut when it had reached a height of about 45 inches while the field cured Sudax hay was cut in the early boot stage of maturity.

Table 4. Chemical composition and digestible dry matter content of forages used.

	Percent, dry matter basis						
	Crude protein	Ether extract	Crude fiber	Ash	NFE	ADL*	DDM
Ryegrass(immature)	16.1	2.4	25.6	9.2	46.7	4.0	67.1
Alfalfa	21.2	1.8	25.0	8.5	43.5	7.5	63.3
Coastal bermuda	7.9	1.6	29.8	5.6	55.1	5.8	53.1
Sudax 6/29	21.1	2.3	25.6	13.9	37.1	4.9	62.2
Sudax hay (field cured)	13.0	1.1	32.8	9.3	46.6	6.2	52.3

* Van Soest's acid-detergent lignin

At 60°F the ryegrass, alfalfa and Coastal bermuda were readily consumed. The Sudax hays were not consumed quite as well; however, the early cut Sudax was consumed at a rate considerably better than the field cured Sudax. The physical form of the chopped Sudax hay may have been a limiting factor in the amount the sheep would eat.

At 90°F less forage was consumed regardless of the kind fed. The greatest decrease in dry matter intake was with the alfalfa hay. At 60°F the alfalfa was consumed readily by the sheep, but it was more difficult to keep the sheep on alfalfa at high temperature levels. The decrease in dry matter intake with an increase in temperature was least with the early cut Sudax, suggesting that although temperature did affect the intake of the early cut Sudax, some other factor(s) limits intake of this material first. Regardless of the temperature levels at which the hay was fed the highest digestible dry matter intake, expressed as percent of body weight, was with the ryegrass hay.

Table 5. Effect of environmental temperature on dry matter and digestible dry matter intake by sheep fed several forages.

	Dry matter intake % BW		Digestible dry matter intake % BW	
Forage	$60^{o}F$	$90^{o}F$	$60^{o}F$	$90^{o}F$
Ryegrass	3.20	2.57	2.15	1.73
Alfalfa	3.18	2.17	2.01	1.37
Coastal bermuda	3.03	2.52	1.61	1.34
Sudax 6/29	2.72	2.49	1.69	1.55
Sudax hay (field cured)	2.00	1.57	1.05	.82

At $60^{o}F$ the digestible dry matter intake, in decreasing order, was with ryegrass, alfalfa, early cut Sudax, Coastal bermuda and the Sudax hay. At $90^{o}F$, however, the digestible dry matter intake in decreasing order was ryegrass, early cut Sudax hay, alfalfa, Coastal bermuda and the late cut Sudax hay. The digestible dry matter intake was significantly greater with alfalfa than with Coastal bermuda at $60^{o}F$ with very little difference between the two forages at $90^{o}F$. The digestible dry matter intake from early cut Sudax was not as high as the alfalfa and only slightly higher than Coastal bermuda at $60^{o}F$, but markedly superior to either alfalfa or Coastal bermuda at $90^{o}F$. There was a highly significant effect of kind of forage and temperature level on digestible dry matter intake and a highly significant temperature level X forage interaction.

SUMMARY AND CONCLUSIONS

A series of intake trials with mature wethers were conducted at several environmental temperature levels. In the first study three rations- (1) a high concentrate ration, (2) a 30% cellulose ration and (3), a 30% polyethylene ration - were each fed at four constant temperature levels- 55, 70, 85 and 100 degrees F. As environmental temperature increased from 55 to $85^{o}F$, dry matter and digestible dry matter intake decreased similarly for all rations. However, as temperature was increased to $100^{o}F$, intake of the cellulose ration dropped very sharply. This resulted in a highly significant temperature X ration interaction with respect to both dry matter and digestible dry matter intake.

In a second study, five forages were fed alone at temperature levels of 60 to 90°F. Again there was a highly significant temperature X forage interaction with respect to dry matter and digestible dry matter intake.

These studies have several practical implications. First, they clearly suggest that any forage evaluation scheme in which intake is considered the environmental temperature and probably the humidity at the time the forage is fed should be taken into account. Second, these studies suggest that certain rations and forages are superior during periods of hot weather. This, of course, has been recognized by dairymen and feedlot operators in the formulation of rations for summer. The value of having ample, high quality forage on summer pastures is indicated. Finally, these studies suggest that if more was known about chemostatic and thermostatic control of appetite and the interaction of these with ration composition and environmental temperature it may well be possible to develop, through breeding methods, forages more uniquely suited for summer pastures.

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C Effects of Energy Concentration and Physical Form of the Ration on Voluntary Food Intake in Ruminants -
M. J. Montgomery

In Experiment I four completely pelleted rations consisting of the following alfalfa meal: ground shelled corn ratios--100:0, 80:20, 60:40, and 40:60--were fed to eight Holstein heifers in two 4 x 4 Latin-squares and to 40 crossbred lambs in a 67-day continuous feeding trial. Apparent digestibility determined with heifers indicated an increase in dry matter and gross energy digestibility coefficients as the percent corn was increased in the diet. Daily dry matter consumption decreased as the corn increased, and daily energy consumption was similar for all rations.

Results of the lamb trial gave similar trends in dry matter consumption. There was no significant difference ($P \angle 0.05$) in average daily gains (lb/day) for the four experimental rations. ADG were 0.64, 0.66, 0.61, and 0.60 for increasing increments of corn. Carcass grades, loin eye fat, and rib fat were not significantly different ($P \angle 0.05$).

Results of both trials support the hypothesis that ruminants will adjust voluntary food intake in relation to physiological demand for energy if fill or rumen load does not limit their consumption.

In Experiment II eight rations varying in physical form and energy concentration were fed to 12 Holstein heifers in a partially balanced incomplete block design. Total ration dry matter intake was increased when pelleted corn was fed with long-oat straw and long-alfalfa hay compared to the roughages fed alone. Grinding of the oat straw decreased intake, whereas grinding and pelleting of the alfalfa hay increased consumption. Pelleted rations composed of 50% roughage and 50% corn resulted in higher digestible energy intake than the corresponding ground or pelleted roughages.

Addition of corn to the roughage diets increased dry matter digestibility, decreased the digestibility of cellulose, and increased rumen retention time for the roughage part of the diet.

Gastrointestinal tract fill increased as dry matter intake increased. The data indicated that a more accurate method of estimating the space-occupying characteristics of a feed is needed, to verify the bulk or rumen load theory of food intake regulation in ruminants.

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TABLE I

SUMMARY OF DATA FROM EXPERIMENT I

	Ration			
	A (100:0)	B (80:20)	C (60:40)	D (40:60)
Heifer Data				
Dry Matter Intake (% B.W.)	2.28[a]	2.01[b]	1.82[bc]	1.68[c]
Dry Matter Dig. (%)	55.9[a]	60.3[b]	64.6[c]	68.9[d]
Protein Dig. (%)	62.2[a]	61.6[a]	62.1[a]	63.6[a]
Cellulose Dig. (%)	45.3[a]	43.7[a]	38.5[b]	31.5[c]
Gross Energy Dig. (%)	53.6[a]	60.0[b]	64.5[c]	68.7[d]
NVI	71.5[a]	69.0[a]	65.3[a]	65.6[a]
DE Intake (kcal/$Wkg^{.75}$)	244.7[a]	242.4[a]	235.2[a]	234.6[a]
EME Intake (")	195.7[a]	199.5[a]	199.0[a]	203.9[a]
ENE Intake (")	103.1[a]	104.3[a]	105.9[a]	111.3[a]
EHI (")	92.6[a]	95.2[a]	93.1[a]	92.6[a]
Fill (g/$Wkg^{.75}$)	94.4[a]	86.9[ab]	82.2[b]	82.4[b]
Lamb Data				
Dry Matter Intake (% B.W.)	5.35[a]	4.41[b]	3.61[c]	3.30[d]
ADG (lb)	0.63[a]	0.66[a]	0.61[a]	0.60[a]

[a]Values with same superscript are not significantly different at $P < 0.05$.

TABLE II

SUMMARY OF DATA FROM EXPERIMENT II

Constituent	Ration 6: Ground Oat Straw	2: Long Oat Straw	4: Long Straw Plus Corn	1: Long Hay	8: Pelleted Straw & Corn	5: Pelleted Hay	3: Long Hay Plus Corn	7: Pelleted Hay & Corn
DM Intake (% B.W.)	0.83^{a}	1.07^{a}	1.71^{b}	1.86^{bc}	1.90^{bc}	2.24^{d}	1.99^{cd}	1.98^{c}
NVI ($g/W_{kg}^{.75}$)	20.2^{a}	25.9^{a}	55.2^{b}	56.7^{b}	60.4^{b}	69.5^{c}	73.7^{c}	72.8^{c}
DE Intake ($Kcal/W_{kg}^{.75}$)	72.1^{a}	89.4^{a}	197.8^{b}	206.9^{c}	219.8^{c}	252.8^{d}	271.4^{d}	271.8^{d}
GI Tract Fill ($g/W_{kg}^{.75}$)	89.9^{a}	94.0^{a}	116.5^{b}	142.6^{cd}	133.0^{bc}	164.3^{d}	120.5^{b}	126.3^{bc}
Est. Heat Inc. ($Kcal/W_{kg}^{.75}$)	39.2^{a}	47.6^{a}	81.1^{b}	92.8^{b}	93.4^{b}	114.5^{c}	115.5^{c}	118.5^{c}
Blood Sugar (mg/100 ml)	51.9^{a}	53.1^{ab}	56.5^{b}	61.5^{c}	63.7^{c}	62.8^{c}	64.0^{c}	64.4^{c}
Digestibility Coefficients								
Dry Matter	41.4^{a}	45.3^{a}	59.7^{b}	55.9^{b}	57.9^{b}	56.8^{b}	67.5^{c}	69.2^{c}
Cellulose	58.9^{ef}	63.7^{f}	53.5^{de}	57.4^{de}	44.2^{b}	46.9^{bc}	51.7^{cd}	33.4^{a}
Rate of Passage								
(Roughage (hr))	89.4^{c}	72.6^{ab}	78.7^{bc}	73.1^{ab}	69.5^{ab}	65.1^{a}	78.6^{bc}	72.5^{ab}
Rumen Data								
Acetic acid (mg/100 ml)	269.1^{abc}	261.3^{a}	298.0^{abc}	396.8^{de}	332.7^{bcd}	440.7^{e}	345.0^{cd}	307.4^{ab}
Propionic "	60.7^{a}	61.5^{a}	91.5^{ab}	130.9^{bcd}	100.4^{abc}	134.7^{cd}	164.0^{de}	194.5^{e}
Acetic (% of total)	74.2^{d}	72.3^{d}	63.8^{c}	63.7^{c}	62.5^{c}	64.5^{c}	55.7^{b}	48.1^{a}
Propionic "	16.8^{a}	17.1^{a}	20.0^{a}	20.7^{a}	18.7^{a}	19.4^{a}	26.2^{b}	29.3^{b}
Acetate:Propionate	4.4^{c}	4.3^{c}	3.2^{b}	3.1^{b}	3.4^{b}	3.3^{b}	2.2^{a}	2.1^{a}

[a] Ration values with the same superscript are not significantly different at $P < 0.05$.

C✓

~~SUMMATION~~: Where Do We Stand; Where Are We Going; Where Should We Go? - J. T. Huber

I. Current Status

As very ably covered by the previous speakers, there are many controls on the appetite and many factors affect palatability in ruminants. Some of the more pertinent ones will be re-emphasized.

Digestive tract capacity

As suggested by Montgomery (6), and by Van Soest (11), digestive tract capacity (or rumen fill) is most important in controlling intake of rations of relatively low nutrient concentration. In Ohio work (2) with conventional rations (long hay and concentrate in the meal form), the dry matter digestibility at which body size failed to be the main factors associated with intake was 66%. Montgomery (6) noted that this level was considerably lower with pelleted rations. It was suggested that ration density plays an important role in this relationship.

As proposed by Van Soest (11), the positive relationship between intake and digestibility of grasses and legumes is probably related to rumen fill because of the lower cell-wall mass occupying the digestive tract per unit of intake of the more digestible forage. It would also seem that the most tenable theory for the higher intake of ground and pelleted hay compared to long is the increased rate of passage of the ground and pelleted material as indicated by the larger size of fecal particles (11). This faster passage would result in less rumen fill per unit of feed consumed.

Recent studies by Waldo et al. (12) have shown that the depressed intake of high moisture silage was not due to a limited rumen capacity or to more feed residues in the lower gut. Furthermore, no difference in rumen retention time was noted between high moisture silage and hay. Unpalatable fermentation products, such as amines and aldehydes and possibly certain organic acids, although some doubt has been cast on these which are released during ensiling seem to offer the most plausible explanation at the present time for this depression (8).

Chemostatic and thermostatic controls

As mentioned by Jacobson (4) some very interesting and productive studies have recently shown that appetite in ruminants can be depressed by intraruminal, intraperitoneal or intravenous infusions of acetate, propionate, less consistently butyrate and mixtures of these VFA's. It has also been established that the "glucostatic" control which functions in simple-stomach animals is not applicable to ruminants. Other compounds, such as serum amino acids, have been shown to influence appetite in some species, particularly when a nutrient deficiency is present.

Many studies have shown an inverse relationship between environmental temperature and feed intake with the greatest depression occurring at the higher range of temperatures. Riewe (9) reported that the effect of increasing environmental temperature on dry matter intake is different for different forages. At hot environmental temperatures the usual physical and chemical controls are probably of less importance than the heat increment of a feed. However, as stated by Jacobson (4), the temperature effect would probably not become operative until after compensatory mechanisms for thermoregulation had been stressed sufficiently to affect the temperature of the blood flowing to the CNS.

Palatability

Much information has accumulated on the comparative intake of different feeds and many of the differences noted have been related to certain characteristics of the feeds. However, little is known as to why the animal prefers one feed to another. For example, Fontenot and Blaser (3) reviewed studies showing that ruminants prefer the green, leafy parts of plants to the stemmy portions but the physiological basis for this preference needs further clarification.

II. Direction of Intake Studies

Many stations have well-organized projects to study voluntary intake. Some of these are proving quite productive as evidenced by the reports you have heard this morning. In a cooperative way, the S-45, NE-24, NC-64, and W-34 Regional Projects all have as one of their main objectives to develop methods (both *in vivo* and *in vitro*) for measuring and predicting the voluntary intake of forages. These improved methods should give a great impetus to intake studies. They should provide more efficient and precise ways of determining and estimating intake and lead to a better understanding of factors controlling appetite and palatability.

III. Suggested Areas for Future Research

Satiety

Clearly establish the mechanisms of the VFA effects on satiety including site or sites of action. Investigate other substances which may be signal compounds for satiety. Relating of chemostatic controls insofar as possible, to natural feeding conditions would be worthwhile. More studies such as those by Simkins et al. (10) where satiation was associated with maximum concentrations of blood and rumen VFAs are needed.

Taste

Fundamental studies on taste are needed. Some considerations are:

How does taste develop in ruminants: Why does the ruminant desire to eat one feed in preference to another as in the case of choosing the leafy portion of grasses and legumes? How do ruminants react to the conventional taste categories of sour, sweet, bitter, etc? What influence does odor have on acceptability of a feed by ruminants?

Associate factors

Do ruminants prefer a variety of feeds? Are there particular combinations which will result in higher intake than other combinations? In studies we conducted a few years ago, higher intakes and weight gains in heifers were noted when corn and grass silages were offered in combination than when they were offered separately (Table 1).

Table 1. Effect of Corn and Grass Silages Fed Singly and in Combination to Dairy Heifers

	Corn	Grass	Combination
Silage intake (lb/DM/100 lb. BW)	1.90	2.13	2.38
Avg. Daily gain (lb/day)	1.05	1.04	1.66

Supporting this combination effect are the studies of Miller et al. (5) who reported higher forage consumption when Coastal bermudagrass and Tift sudangrass silages were fed in combination than when either was fed alone. The same group (1) has since reported higher intakes and milk production in cows consuming a combination of bermudagrass pellets and corn silage than was noted when these forages were fed singly even though the single forage diets were nutritionally adequate by present standards. Clarification of the underlying reasons for the combination effect is needed.

Methods

Considerable research is in progress on evaluation of old and development of new intake methods. Some of the problems associated with such research have been reviewed (7). To test those methods that appear most promising in different laboratories and locations more cooperative ventures such as that being undertaken by the Forage Evaluation Research Group region might be initiated. Much of what this group learned in designing and conducting such studies can be applied to future endeavors.

The development of techniques for better estimates of intake in group-feeding operations is greatly needed. This is particularly true for silage feeding in automated systems. The refinement of prediction methods based on certain qualities of the forage will help, but it would seem that direct ways of measuring intake of group-fed animals are also necessary. We are thinking of distributing an indigestible marker in silage at time of ensiling. Feces samples will be collected from all cows at periodic intervals and analyzed for marker concentration. Using established values for estimating digestibility of the feed, intakes could then be calculated. A search for internal markers in silages would be another approach.

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Annual Business Meeting - W. B. Anthony, Presiding

The annual business meeting of Southern Pasture and Forage Crop Improvement Conference was called to order at 11:50a.m., June 15, 1966, by Chairman W. B. Anthony. A registration of 80 to 85 was announced for the Conference. Chairman Anthony expressed thanks to all concerned for their cooperation and fulfilment of responsibilities in Conference program. Summaries of the morning's program by Animal Science and Plant Breeding and Genetics Interest Groups were given by William Chalupa and Robert Buckner, respectively. Summaries of all papers were requested by Chairman Anthony, for inclusion in the Conference report.

The report of the Resolutions Committee was given by Robert Buckner as follows: "Resolved: That the Southern Pasture and Forage Crop Improvement Conference hereby expresses the sincere appreciation of its membership to the administration and staff of the Virginia Polytechnic Institute for the fine facilities, excellent program and tour arrangements, and true Virginia hospitality provided to the Conference and to the several technical working committees and subcommittees associated with the Conference. The Commonwealth of Virginia is also to be commended for its program of pasture and forage crop improvement research and the awareness of its leadership in the importance of pasture and forages in the economy of the State."

The Resolutions Committee requested that the above resolution be sent to the President, Dean of Agriculture, Director of Experiment Station, and Head of Department of Agronomy of Virginia Polytechnic Institute, by the Permanent Secretary. The Resolution was adopted unanimously.

Chairman Anthony read a letter from Director Doyle Chambers, Louisiana Agricultural Experiment Station, extending an invitation to Southern Pasture and Forage Crop Improvement Conference to hold its 1967 conference at Louisiana State University. A motion to accept the invitation was passed unanimously.

Chairman Anthony announced a meeting of the Executive Council immediately after the adjournment of the general business meeting.

The Report of the Nominations Committee was given by Roy Blaser as follows: "In making nominations the Committee considered representation of plant and animal interests. Because of his interest in animals and forages, the Committee presents Mr. Marvin Riewe of Texas for consideration."

A motion to close nominations and to instruct the Chairman to cast an unanimous ballot for Mr. Marvin Riewe as Chairman Elect-Elect of SPFCIC was passed unanimously. The Chair was passed to Henry Fribourg by W. B. Anthony, and Chairman Fribourg adjourned the meeting at 12:07 p.m.

PLANT BREEDING AND GENETICS INTEREST GROUP
Room 223, Biochemistry Building

R. C. Buckner, University of Kentucky, Presiding

C

Biosystematics of the Genus Cynodon (Gramineae). - Jack R. Harlan, J. M. J. de Wet, W. R. Richardson, W. W. Huffine, John Deakin, S. P. Sen Gupta, and Azucena Carpena

This is the second report of progress on a study of "The Biosystematics of the genus *Cynodon*" supported in part by National Science Foundation Grants Nos. GB 201 and GB 2686. The entire collection was grown in the field again in 1965 plus some 1200 plants derived from the hybridization attempts of Mr. Richardson. A selected sample was studied by methods of numerical taxonomy using a match-mismatch ratio and cluster analysis. Morphological and cyto-taxonomic studies were continued. At the present time we feel that we can identify the taxa present and understand the major evolutionary mechanisms in the genus. Final decisions concerning the ranking of the taxa, however, must await further studies of the large number of hybrids made during the winter of 1965 - 1966. Some varieties may eventually be raised to specific rank, or some species in the present provisional classification may be reduced to varieties. The decisions are difficult because the morphogenetic discontinuities are different in size and degree between the various units.

From the start of the study it was evident that the collection contained some materials which have not been properly named or not named at all. Among the robust East African collections, for example, are units that are obviously not *C. plectostachyus* (Schum.) Pilger. These were grouped in our 1964 Report under *C. ruspolianus* Chiov., but when we finally obtained the type description of *C. ruspolianus*, ~~it~~ was evident that *C. ruspolianus* is *C. plectostachyus*. This leaves a large group of accessions without appropriate names. To make sense of the robust East African forms we have found it necessary to add three new taxa. One of these is sufficiently like *C. coursii* A. Camus that it can be included as a diploid variety, *C. coursii* var. *africanus* de Wet et Harlan var. nov. The other two taxa are clearly neither *C. plectostachyus* nor *C. dactylon* and we are adding the epithets *C. aethiopicus* and *C. robustus*. There are diploid and tetraploid races of both of these species.

The morphogenetic discontinuities between varieties of *C. arcuatus* and of *C. incompletus* appear either too minor or too inconsistent to be maintained, and these are dropped in the present classification. The variety *C. dactylon* var. *laxus* appears to be a very definite and consistent taxon and may deserve specific rank. A decision on this point must await further studies of the hybrids in which it is involved. We consider the classification offered in this progress report to be an improvement over the one used in the 1964 report, but it is still provisional.

The evolutionary pattern in *Cynodon* is classical and conservative. Normal sexual speciation has gone on over a long period of time resulting in rather well defined, genetically distinct taxa which do not hybridize to any great extent even when growing together. Introgressive hybridization is not a conspicuous feature in the genus and usually involves *C. dactylon*

when it does occur. The most characteristic evolutionary mechanism is autoploidy. Most of the species have diploid and tetraploid chromosome races, and all lines of evidence indicate the 4x forms are primarily autotetraploids rather than alloploids. Our crossing studies indicate clearly the probable mode of origin. We find that unreduced gametes, both male and female function at an unexpectedly high frequency. Within C. dactylon, translocation races are common, and this mechanism has fragmented the species with numerous partial sterility barriers.

Chromosome paring in interspecific crosses is preferrential but strongly autosyndetic and does not reveal very much about the degree of relationship among the various taxa. The ease or difficulty of making specific combinations and the vigor and fertility of the hybrids may be more revealing. For example, out of a large number of attempts the only hybrids we could obtain (so far) with diploid C. afghanus were those in which unreduced gametes were involved. Diploid x diploid crosses are, predictably, much more difficult to make than tetraploid x tetraploid or even tetraploid x diploid. At the diploid level, we find that diploid C. dactylon, diploid C. coursii, and C. transvaalensis cross rather easily one with the other. Other diploid combinations are extremely difficult or impossible to make. At the tetraploid level, however, all combinations are probably possible except that C. arcuatus appears to be completely isolated even at the tetraploid level. The following provisional classification is offered in this report:

1. Cynodon aethiopicus Harlan et de Wet sp. nov.

No. whorls in inflorescence: 1 - 4, usually 2 or more.
Racemes: Stout, often appressed, few to 10 or more, red.
Spikelets: medium to wide spacing on racemes, ca. 3.5 mm.
Glumes: subequal, about 3/5 spikelet length.
Lemma: pointed, hairy on keels.
Stolons: stout, long internodes
Rhizomes: none.
Leaves: linear lanceolate, coarse, stiff and harsh, glabrous or sparsely hairy.
Chromosome number: 2n=18, 36.
Prussic acid content: low to medium
Growth habit: tall, coarse, culms hard, shiny, rather woody, vigorously spreading by coarse stolons.
Habitat: coastal plain to highlands, absent in dry regions.
Distribution: Ethiopia, Kenya, Tanzania, Zambia, Uganda (?).
Remarks: Inflorescence shape is rather like true C. plectostachyus but smaller and usually pigmented dark red. Spikelets are much more like C. dactylon, but rhizomes are wanting and the growth habit is quite distinctive.

2. Cynodon afghanus Harlan et de Wet sp. nov.

No. whorls in inflorescence: 1-2.
Racemes: stout, stiff, broad
Spikelets: closely imbricate on racemes, ca. 4 mm.

Glumes: ca. 3/4 spikelet length.
Lemma: Rather blunt, hairs on keel.
Stolons: slender, long looping internodes, rapid spreading.
Rhizomes: few and deep in diploids; short and poorly developed or few in tetraploids.
Leaves: linear lanceolate, rather long, widely spaced.
Chromosome number: 2n = 18, 36
Prussic acid content: low.
Growth habit: Very loose and lax sod, spreading by long, slender stolons, seed heads abundant and seed set excellent.
Habitat: Lowland steppes of Afghanistan, the diploids from Paropamisus northward; the tetraploids both north and south.
Distribution: Afghanistan
Remarks: This species appears to differ from the so-called 'giant' types although the growth habits are similar.

3. Cynodon arcuatus Presl

No. whorls in inflorescence: 1.
Racemes: Very long, slender, flexuous, broadly spreading or recurved.
Spikelets: Rather closely arranged on raceme, ca. 3 mm.
Glumes: subequal, about 1/2 spikelet length.
Lemma: pointed, somewhat hairy on keel.
Stolons: slender, rather short internodes, often red in color.
Chromosome number: 2n = 36; Rhizomes: none.
Leaves: very broadly lanceolate, sometimes red pigment conspicuous.
Prussic acid content: medium to high, occasionally low.
Growth habit: very characteristic growth forming low, loose mats with broad leaves and a tangle of inflorescences above; prolific seeder.
Habitat: rather weedy in wet areas; lowlands.
Distribution: Island of Nossibe in Malagasy to Ceylon, South and East India, Southeast Asia to northern Australia.
Remarks: A very distinctive and easily recognized species and genetically isolated from other species in the genus.

4. Cynodon barberi Rang. et Tad.

No. whorls in inflorescence: 1.
Racemes: short, slender, delicate.
Spikelets: rather widely spaced on racemes, ca. 3 mm or less.
Glumes: rather unequal, the longest slightly exceeding the lemma.
Lemma: pointed somewhat hairy on keel.
Stolons: very fine, slender, short internodes, often red.
Rhizomes: none
Leaves: short, broadly lanceolate with long, sparse hairs, sometimes with red pigment.
Chromosome number: 2n = 18.

Prussic acid content: low.
Growth habit: The slender stolons from loose mats less than 1 decimeter in height, very distinctive.
Habitat: Wet ground and permanent waterways.
Distribution: South India.
Remarks: Except for the very different inflorescence, this species suggests a miniature version of C. arcuatus. Genetically well isolated from other species; the long glumes suggest affinity to Brachyachne.

5. Cynodon coursii var coursii A. Camus

No. whorls in inflorescence: 1, rarely 2.
Racemes: stout, spreading, averaging 5 - 6.
Spikelets: medium spacing on raceme, ca. 4 mm.
Glumes: subequal, ca. 3/4 spikelet length.
Lemma: hairy on both keel and margins.
Stolons: medium coarse.
Rhizomes: none
Leaves: Linear lanceolate, rather wide, bunched and appressed at tip of culm, glabrous or nearly so.
Chromosome number: $2n = 36$.
Prussic acid content: low to medium.
Growth habit: tall, coarse, distinctive, the foliage making a pile some 4 - 5 decimeters high; the upper leaves of the culms and aerial stolons bunched, ascending and appressed.
Habitat: usually on disburbed sites (rather weedy).
Distribution: The central plateau of Madagascar.

5a. C. coursii var africanus de Wet et Harlan var. nov.

No. whorls in inflorescence: 1, rarely 2.
Racemes: more slender and flexible than preceding variety, avg. ca. 5 - 6.
Spikelets: rather widely spaced on racemes; ca. 4 mm.
Glumes: subequal, about 3/4 spikelet length.
Lemma: pointed, hairy on keel, sometimes hairy on margins.
Stolons: medium to stout, long internodes.
Rhizomes: none.
Leaves: Linear lanceolate, rather wide, glabrous or sparsely hairy.
Chromosome number: $2n = 18$.
Prussic acid content: Low to medium
Growth habit: Vigorous, coarse growth forming rather dense mats, but tending to lack the bunching of the ascending terminal leaves and piling habit of the preceding variety.
Habitat: Coastal plain to the highlands in damp areas, usually along the banks of streams.
Distribution: Ethiopia, Kenya, Tanzania, Rhodesia, Uganda (?).
Remarks: Differs from preceding variety in chromosome number, distribution, habitat, growth habit, and in many cases, the lemma is hairy on the keels only.

6. Cynodon dactylon var. dactylon (L.) Pers.

No. whorls in inflorescence: 1, sometimes 2 or more.
Racemes: rather slender, stiff, spreading 2 to several.
Spikelets: spacing on raceme medium to wide, ca. 3 mm.
Glumes: variable, mostly 1/2 to 3/4 spikelet length or sometimes more.
Lemma: glabrous or somewhat hairy on keel.
Stolons: very fine to rather coarse, but never as stout as the robust East African species C. plectostachyus, C. robustus and C. aethiopicus.
Rhizomes: present, slender to stout and fleshy.
Leaves: linear lanceolate, always finer than the robust East African spp.; sometimes strongly pilose.
Chromosome number: 2n = 18, 36.
Prussic acid content: Almost always low; rarely medium.
Growth habit: Extremely variable from very small, fine, turfy types to medium robust forage types, but always smaller than the robust East African spp.
Habitat: The diploids of South India confined to wet areas; other diploids to rather dry regions; the tetraploids weedy and cosmopolitan, segetal.
Distribution: Now pantropical and in warm-temperate regions around the world, but reaching southern England and Germany in Europe and Michigan in the USA.
Remarks: The large diploids with long bluish leaves and long, slender, fast growing stolons, adapted to rather dry regions of Asia and Africa would appear to include the types called 'Giant' in southwestern USA. They are insufficiently known to be given a name at the present time.

6a. C. dactylon var. laxus de Wet et Harlan var. nov.

No. whorls in inflorescence: 1, very rarely 2 or more.
Racemes: Rather slender, stiff, ascending.
Spikelets: Spacing on raceme medium; ca. 4 mm.
Glumes: 1/2 to 3/4 spikelet length.
Lemma: Somewhat hairy on keel.
Stolons: Medium coarse, long.
Rhizomes: Present, slender to fleshy.
Leaves: Linear lanceolate, stiffly ascending, often hairy.
Chromosome number: 2n = 36.
Prussic acid content: low
Growth habit: The clearly decumbent culms with ascending leaves forming a lax, loose sod and conspicuously distinct growth habit.
Habitat: Coastal plain to Karroo and Highveld, somewhat weedy but a part of natural vegetation.
Distribution: South Africa, Mozambique, Rhodesia to southern Zambia.
Remarks: This variety is the common C. dactylon of South Africa and consistently distinct from the preceding variety. Despite the large and abundant rhizomes it completely lacks winter hardiness at Stillwater, Oklahoma.

6b. _C. dactylon_ var. _polevansii_ de Wet et Harlan comb. nov.

No. whorls in inflorescence: 1.
Racemes: Small, slender, widely spreading; 2 to several often reflexed.
Spikelets: Often angular; spacing on raceme medium to wide; ca. 4 mm.
Glumes: 1/2 to 3/4 spikelet length.
Lemma: Pointed, hairs on keel.
Stolons: Rather fine short internodes.
Rhizomes: Present, small.
Leaves: Linear lanceolate, small, fine, stiffly ascending, glabrous to somewhat hairy.
Chromosome number: $2n=36$.
Prussic acid content: low
Growth habit: The harsh, stiffly ascending leaves give a characteristic aspect to the plants which are otherwise rather small and turfy.

Habitat: Saline soils of the dry Karroo.
Distribution: South Africa.
Remarks: The type specimen is so depauperate, presumably from close grazing prior to collection, that little can be made of it. The type site at Barberspan, however, is well described and we feel sure that we have collected the same material. When grown to full development in the nursery, it turns out to be neither a separate species nor _C. transvaalensis_, but a variety of _C. dactylon_ which we have been able to match very closely in artifically produced hybrids between _C. dactylon_ var. _dactylon_ and _C. dactylon_ var. _laxus_. It does have a very characteristic growth habit and we retain varietal status for it.

7. _Cynodon incompletus_ Nees

No. whorls in inflorescence: 1.
Racemes: Slender, stiff; 2 to several, often reflexed.
Spikelets: Rather widely spaced on raceme; ca. 3.5 mm.
Glumes: 1/2 to 3/4 spikelet length.
Lemma: Often rather blunt; hairy on keel.
Stolons: Fine, slender, short internodes; often pigmented dark red.
Rhizomes: None
Leaves: Linear lanceolate; small, moderately to densely hairy.
Chromosome number: $2n=18$, rarely 36.
Prussic acid content: low, medium, and high with no obvious pattern.
Growth habit: Low, rather dense sod; ungrazed plants making a rather characteristic pile of foliage some 2 decimeters high.
Habitat: Highveld and semi-arid Karroo of South Africa, somewhat weedy, but part of natural vegetation.
Distribution: Southern Africa from the Cape to about 23° south latitude.
Remarks: The species is rather variable and includes material named _C. bradleyi_ and _C. hirsutus_ which cannot be consistently distinguished.

8. <u>Cynodon</u> <u>plectostachyus</u> (Schum.) Pilger

No. whorls in inflorescence: 1 to 7; almost always 2 or more.
Racemes: large, stout, stiff.
Spikelets: Rather closely spaced on raceme: 3.75 to 4 mm.
Glumes: 1/4 spikelet length to almost wanting.
Lemma: Pointed elliptical, conspicuously hairy on both margins and keels.
Stolons: Large, stout, long internodes.
Rhizomes: None.
Leaves: Linear lanceolage, wide, soft to the touch, hairy.
Chromosome number: $2n = 18$.
Prussic acid content: medium to high.
Growth habit: Large, robust plants with thick stolons and culms, wide, soft and hairy leaves; very distinctive.
Habitat: areas of rather high rainfall along the highlands of East Africa.
Distribution: Ethiopia, Kenya, Tanzania, Zambia, Uganda, Congo.
Remarks: The type description of <u>C</u>. <u>ruspolianus</u> indicates it to be a synonym of <u>C</u>. <u>plectostachyus</u>.

9. <u>Cynodon</u> <u>robustus</u> de Wet et Harlan sp. nov.

No. whorls in inflorescence: 1, rarely 2.
Racemes: very long, spreading, often rather flexuous, averaging ca. 5.
Spikelets: Rather widely spaced on raceme; 3.5 to 4 mm.
Glumes: The longest more than 3/5 spikelet length.
Lemma: pointed; sparsely hairy on keel.
Stolons: Stout, long internodes.
Rhizomes: None.
Leaves: Linear lanceolate, soft like <u>C</u>. <u>plectostachyus</u>, but glabrous or nearly so.
Chromosome number: $2n = 18$, 36.
Prussic acid content: Medium to high.
Growth habit: tall, coarse, but with soft foliage, spreading vigorously by coarse stolons.
Habitat: high rainfall areas of East African highlands.
Distribution: Ethiopia, Kenya, Zambia, Uganda, Tanzania.
Remarks: Differs from <u>C</u>. <u>plectostachyus</u> in shape of inflorescence, length of glumes, lack of hair on margins of lemma, and glabrous to sparsely hairy foliage; differs from <u>C</u>. <u>dactylon</u> in lacking rhizomes, high prussic acid content, length of racemes, size of spikelets, and growth habit.

10. <u>Cynodon</u> <u>transvaalensis</u> Burtt-Davy

No. whorls in inflorescence: 1.
Racemes: Fine, small, stiff.
Spikelets: Spacing on racemes medium; up to 4 mm. long.
Glumes: rather unequal, the longest ca. 3/4 spikelet length.
Lemma: Pointed, slightly hairy on keel.
Stolons: Very fine, short internodes, pigmented dark red.
Rhizomes: Present, small and fleshy.
Leaves: Linear lanceolate, slender, ascending, yellowish green cast, hairy.
Chromosome number: $2n = 18$.

Prussic acid content: low.
Growth habit: Fine-textured turf, rather easily identified by the pale green color and fine ascending leaves.
Habitat: Usually in damp areas near permanent waterholes and weedy near houses and urban areas; also cultivated as turfgrass.
Distribution: Western and southwestern Transvaal to northwestern Cape province of South Africa; widely cultivated as turfgrass.

11. Cynodon X maginnessii Hurcombe

No. whorls in inflorescence: 1.
Racemes: Small, slender, few.
Spikelets: Widely spaced on raceme; ca. 3 mm.; sterile.
Glumes: Ca. 2/3 spikelet length.
Lemma: Pointed; slightly hairy on keel.
Stolons: Very fine, short internodes.
Rhizomes: Very short, shallow, small.
Leaves: Linear lanceolate, often dark green, fine, hairy.
Chromosome number: $2n=27$.
Prussic acid content: Low.
Growth habit: Fine, low-growing, dense turf; commercially known as 'sunturf.'
Habitat: Lawns under cultivation.
Distribution: Only one cultivated clone known; rather widely used as a turfgrass. Origin in South Africa.
Remarks: We have other triploids in our collection, but they are all somewhat different; this one is presumed to be between C. dactylon var. dactylon and C. transvaalensis.

Evaluation of Orchardgrass Progenies as Spaced Plants - R. A. Mohror and L. H. Taylor.

Space planted trials may be useful for evaluating orchardgrass progenies of which only limited quantities of seed are available if the yields obtained are related to yields in broadcast seedings.

Two trials of experimental orchardgrass synthetic varieties were planted at the Virginia station as broadcast seedings, drilled rows and rows of spaced plants. Significant differences in forage yield between strains and between methods of planting were obtained but no significant strain x method of planting interactions was observed over a 3-year period. The 3 methods of planting did a similar job of ranking the Syn. 1 generation of 8 experimental synthetic varieties in the order predicted on the basis of earlier top-cross yield data for combining ability.

Three maturity groups of experimental synthetic varieties, single crosses and check varieties were evaluated for yield using spaced plants only. In all three groups, some experimental synthetics and single crosses were higher yielding than the best check variety.

As the plot size and spacing (10 plants spaced 1' apart in rows spaced 2' apart) in the above tests were chosen largely for convenience, spacing trials with single-cross progenies of orchardgrass were carried out to study the effects of borders, spacing and competition on the yield performance of spaced plants. Plants were grown at 24" x 24", 12" x 12", and 6" x 6" spacings. Significant border effects were found to extend beyond a single border row at the 6" spacing but not at the 12" spacing.

Analyses of variance of the yield data showed a singificant entries x spacings interaction for single crosses grown at the 24" and 6" spacings. Significant spacing x cuttings interactions indicated that the distribution of yield of the spaced plants throughout the growing season was changed as they were grown under more competitive conditions. A competitive index was calculated and used to predict the effect of an entry on the plot growing adjacent to it. At the 12" spacing, the competitive differences predicted were evident by mid-season and at the 6" spacing competitive effects were greater and were present at the first cutting.

It would appear that spaced plants can be used for yield comparisons of strains of orchardgrass. Border effects, spacing to be used and competitive effects between entries should be considered.

C/

Chromosome Diversity Among the Nigerian Collection of Pearl Millets - Jerrel B. Powell and Glenn W. Burton

A cytological survey of the Nigerian collection of pearl millets was undertaken to determine whether karyotypic variations were present in this material. The analysis was conducted on F_1 hybrids of these lines crossed with our well-established inbred lines. Microsporocytes were examined for chromosome translocations, paracentric inversions and any other chromosome anomaly which could be observed at diakinesis, metaphase I and anaphase I. Two lines were found to contain variable numbers (up to 5 observed) of accessory or "B" chromosomes. This makes a total of three lines in our stocks which are known to have these extra chromosomes. One trisomic plant was found, as well as one plant having bridges and fragments. Several lines had chromosomes which behaved almost as asynaptics when crossed with our standard inbreds. This survey indicates that chromosome diversity in pearl millet follows the extreme genetic diversity exhibited by these same introductions from Nigeria - the region of probable origin of this species.

Effect of Plant Height Genes on Yield of Sudangrass - J. P. Craigmiles

The development of a cytoplasmic male sterile sudangrass resulted in the release of the first hybrid sudangrass in 1961. Although forage yields were superior, seed production was difficult because the extreme height of the sterile did not lend itself to mechanical seed harvesting equipment. To correct this, the height of the A and B lines of Rhodesian sudangrass has been reduced from 12 to 4 feet. This height reduction was due to the transfer of our recessive dwarf genes from Combine Kafir 60 to Rhodesian sudangrass. The pollinator, Tift, containing dominant height factors, restores full height in the F_1 hybrid.

This paper reports the effect of these four height genes on forage yield of the lines and the F_1 hybrids.

Results from three clippings in 1965 indicate no statistically significant difference in forage production of Suhi-1 (tall line x Tift) and Suhi-2 (dwarf line x Tift). As expected, the A and B lines of each hybrid produced essentially the same amount of forage. There were no significant differences in forage production of the dwarf A and B lines and the tall A and B lines, which indicates the four height genes had no significant influence on yield. The dwarf lines had a higher ratio of leaves to stems, however.

title entry

Panel Discussion: PROGRESS ON DEVELOPING PEST RESISTANT ALFALFA
C. H. Hanson, Discussion Leader

Breeding for Pest Resistance in Alfalfa in North Carolina - Thad H. Busbice

At the present time in North Carolina, research in alfalfa breeding is being directed toward finding resistance to the stem nematode (Ditylenchus dipsaci) and the alfalfa weevil (Hypera postica). In areas of North Carolina infested with stem nematodes, it is often difficult or impossible to obtain persistent stands of nematode susceptible but otherwise adapted varieties. The alfalfa weevil has become so destructive that it is no longer practical to grow alfalfa without extensive chemical and cultural control measures.

Breeding research for resistance to stem nematodes began in 1956 when a few surviving plants of DuPuits and Flamande alfalfa varieties were selected from a broadcast planting on stem nematode-infested soil in the Appalachian Mountains of North Carolina. These plants were later shown to contain a moderate level of resistance to stem nematodes. A backcrossing program was begun using the selected DuPuits and Flamande clones as the recurrent parents in a cross with clone C-900, a resistant parent in the stem nematode resistant variety, 'Lahontan'. This backcross program has produced an experimental synthetic designated N1 that is similar to Flemish alfalfa and highly resistant to stem nematodes. Selection for resistance was based upon seedling swelling after inoculation in a laboratory test.

In 1961 through a laboratory test, it was found that 'Cherokee', an adapted variety with a broad genetic base, contained a low percentage of stem nematode resistant plants. Two cycles of recurrent selection in Cherokee has produced an experimental synthetic, designated N2, that displays a moderate level of resistance to stem nematodes.

Table 1 is a comparison of swelling ratings of the experimental synthetics and check varieties taken on seedlings from field plots heavily infested with nematodes. A rating of 1 indicates no swelling and 10 indicates much swelling. The experimental synthetics show significantly (.05 level) less swelling than the check varieties. N1 has been tested for forage yield and has yielded significantly (.01 level) more than Cherokee and DuPuits on stem nematode infested soil. N1 is now being tested on non-infested soils of North Carolina and on infested and non-infested soils of Oregon. N2 is now being tested for forage yield and is expected to yield similarly to Cherokee.

The breeding for resistance to the alfalfa weevil began in 1960 with the findings that Medicago sativa, variety gaetula, was less preferred by the female weevil for oviposition than Atlantic when given a choice between the two.[1/] A backcross program was initiated from the cross, gaetula x Cherokee, with Cherokee as the recurrent parent. Resistance was measured

1/ Campbell, W. V. and Dudley, J. W. Differences among Medicago species in resistance to oviposition by the alfalfa weevil. J. Economic Ent. 58:245-248, 1965.

Table 1. Seedling Swelling[1/] on Stem Nematode Infested Soil at Waynesville, N. C.

Entry[2/]	Mean
N1	2.3
N2	2.6
Lahontan	2.7
DuPuits	3.6
Cherokee	4.1

L.S.D. (.05)= .7

1/ 1 = no swelling 9 = much swelling

2/ N1 is an experimental synthetic developed through a backcross program of C900 x Flemish Selection $(\text{Flemish Selection})^2$

N2 is an experimental synthetic developed through 2 cycles of recurrent selection in Cherokee.

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by the number of egg masses laid per unit of stem when the females were given a choice of genotypes in a preference test. Selections from the BC_2 population were polycrossed to produce an experimental synthetic designated W3. W3 has a low preference rating similar to gaetula and is being tested under field conditions; however, there are no data available on field performance at the present.

In addition to the backcross program, a recurrent selection program has been initiated to select for resistance to alfalfa weevil oviposition in adapted varieties. In this program plants with low numbers of egg masses in a preference test are recombined to produce a population for the next cycle of selection. The results of one cycle of selection have been evaluated. The selected populations had significantly (.05 level) fewer egg masses per Cm^3 of stem than the unselected populations. In this comparison the female were allowed to choose among all entries.

Stem diameter was measured and correlated with egg masses per Cm^3 of stem to determine if preference was related to stem size. A low correlation coefficient of .15, 10 d.f., indicated that no relationship existed between these characters.

From the preference tests we are able to conclude that the alfalfa weevil has the ability to choose between genotypes of alfalfa and oviposit in the preferred genotype, and that it is possible, through selection, to develop alfalfa populations that are less preferred. The question arises "will the female weevil lay fewer eggs in the less preferred population when she is given no choice, that is, will she lay fewer eggs when she

is isolated on the selected populations?

An answer to this question was sought in a forced oviposition test. Individual plants from the preference test were caged in single plant cages and five female weevils were enclosed with each plant. Each of 10 entries was represented by 10 plants in a completely random design. After 10 days, egg masses were counted in each plant and entry means were computed. A correlation between egg masses per Cm^3 of stem in the preference test with egg masses per plant in the forced test gave a low correlation coefficient of -.06 indicating that no relationship existed between these two measurements of oviposition in that test. These results are disconcerting since they suggest that populations with low preference ratings in the laboratory may not show resistance in the field under conditions where the weevil is given no choice. However, more testing is needed in the laboratory and in the field to critically evaluate the effectiveness of preference in the development of resistant synthetics.

Progress in Developing Pest Resistant Alfalfas in Arkansas - M.S. Offutt

The alfalfa breeding program at the University of Arkansas includes work on the development of varieties with resistance to the following insects: (1) Spotted alfalfa aphid (Therioaphis maculata Buckton), (2) Leafhoppers (mostly Empoasca fabae Harr.), and (3) Three-cornered alfalfa hopper (Spissistilus festinus Say.).

Spotted alfalfa aphid - A population of spotted alfalfa aphids is maintained on susceptible alfalfa plants in a laboratory where light, temperature, and humidity are carefully controlled. Susceptible alfalfa clones are maintained by vegetative cuttings in the greenhouse and transferred to the laboratory as needed to maintain the population of spotted alfalfa aphids. Both S_1 and P.C. seed are obtained from promising clones and planted in clonal rows in flats containing about 3 inches of soil. These flats are placed in the laboratory alongside the flats containing the susceptible clones on which the spotted alfalfa aphids are being maintained. When the S_1 and P.C. progeny seedlings are about 1 inch tall, the spotted alfalfa aphids are shaken from the

susceptible plants onto the seedlings being tested. This procedure is repeated every few days for several weeks. Clones with the highest percentage of progeny surviving then are evaluated for other important characteristics in the field. Surviving S_1 and P.C. progeny plants are also transferred to the greenhouse or to the field for further evaluation and use in the alfalfa breeding program.

The procedure outlined above was used in the development of Arkansas Synthetic P-1 alfalfa, which is a 6-clone pasture-type synthetic with about 50% of the plants expressing the creeping-rooted habit by the end of the second year at Fayetteville. Since only very limited infestations of this insect have occurred in the state since seed has been available for testing, it has not been possible to accurately evaluate this synthetic for this characteristic under field conditions in Arkansas. Spotted alfalfa aphid reaction scores from southern Illinois and California indicate, however, that, under their conditions, Arkansas Synthetic P-1 carries a relatively high level of resistance to this insect pest.

Leafhoppers - Experimental synthetics, breeding lines, and promising clones and their progenies are evaluated for tolerance to leafhoppers by the following technique. Plant material to be evaluated is planted in rows next to a solid-planted block of either Lahontan or Buffalo, both of which are yellowed rather severely when infested with leafhoppers. The alfalfa in the solid-planted block is cut first, which causes the leafhoppers in this area to migrate to the adjacent area containing the experimental plant materials. This technique has resulted in reasonably uniform leafhopper infestations of the plant material being evaluated one or more times each season. Only those clones which produce progenies with a relatively high tolerance to leafhopper injury are retained in the breeding program. The above procedure was utilized in selecting the parental clones for the Arkansas Synthetic P-1 and Arkansas Synthetic P-2 alfalfa varieties, both of which have been rated relatively high for tolerance to leafhoppers in experimental plantings in Arkansas.

Three-cornered alfalfa hopper - An attempt is being made to improve the level of resistance to the three-cornered alfalfa hopper in a population of hay-type plants by recurrent phenotypic selection. The program is now in the third cycle of selection. Evaluation of individual plants making up the population in each cycle has been very difficult, however, due to a lack of uniform infestations within the experimental area in any given year. The degree of progress, if any, in developing a population with a higher degree of resistance to the three-corned alfalfa hopper is not known at this time.

Development of Weevil Resistance and Improved Germplasm Pools with Pest Resistance in Alfalfa - C. H. Hanson

A. Development of improved germplasm pools with pest resistance.

In 1950, we initiated the development of 2 broad germplasm pools (pools A and B) and several "subpools" with pest resistance. Simultaneously we tried to retain genetic variability within them for unselected traits. This should enhance the isolation of clones with multiple resistance and good agronomic characteristics for use in synthetic and hybrid combinations. The diagram below shows the selection procedure followed for pool A.

CYCLES OF RECURRENT PHENOTYPIC SELECTION COMPLETED IN DEVELOPMENT OF GERMPLASM POOLS WITH PEST RESISTANCE

CYCLE	KINDS OF RESISTANCE SOUGHT, DESIGNATION OF CYCLES IN POOL A, LOCATION OF WORK AND CITATION			
1	RUST, LEAFHOPPER YELLOWING,	A-1		
TO	PERSISTENCE, RALEIGH, N. C.,	TO		
8	(DUDLEY, ET.AL.)	A-8		
9	LEAFHOPPER YELLOWING	A-L2	A-A2	SPOTTED APHID, CALIF.
10	BELTSVILLE, MD.	A-L3	A-A3	ARIZ., MD.
11	(HANSON, ET. AL.)	A-L4		
12	COMMON LEAFSPOT	A-C2	A-W2	BACTERIAL WILT
13	UNIVERSITY PARK, PA.	A-C3	A-W3	BELTSVILLE, MD.
14	(GRAHAM, ET.AL.)	A-C4	A-W4	(UNPUBLISHED)
15	BACTERIAL WILT, MD.	A-C-W-2		
	(UNPUBLISHED)			

Pool B was subjected to the same selection procedure.

Selection in the two pools was initiated in 1950 by intercrossing healthy plants taken largely from broadcast stands 3 or 4 years old. Parent plants for pool A consisted of 300 plants from Atlantic and 33 plants each from two Kansas synthetics and one Nebraska synthetic. Plants for pool B consisted of 400 plants from Buffalo, Williamsburg, four Kansas synthetics, Du Puits, Oklahoma Common, and Kansas Common. The selected plants were intercrossed within pools to obtain seed for the second cycle. For each cycle, 2000 to 5000 plants were usually observed within each pool and 80 or more plants were selected and intercrossed to obtain seed for the next cycle.

The literature citations at the end describe progress in developing pest resistant and adapted populations for eastern United States. Resistance reaction to some, and perhaps many, disease and insect pests appears to be highly heritable. In such cases, recurrent phenotypic selection in random breeding populations, such as was practiced in pools A and B, is favored over more complex pedigree procedures in the beginning phases of an alfalfa improvement program. There are several reasons. Large populations can be evaluated for resistance at low cost. The probability of recovering individuals with multiple pest resistance is enhanced with each cycle of effective selection. This procedure minimizes the chances of developing resistance with a narrow gene base. In addition, such pools have utility as reservoirs of germplasm. The improved germplasm pool serves as an elevated base on which more refined breeding procedures can be superimposed. Certainly hybrids or synthetics which make maximum use of heterosis must be considered final goals in the more advanced stages of a breeding program in order to attain the last increments of progress for breeding pest resistance, as well as for obtaining maximum yield.

B. <u>Developing resistance to alfalfa weevil</u>. Development of weevil resistant varieties at Beltsville, Md., is a joint endeavor of the Crops and Entomology Research Divisions. During 1965, we strengthened our Crops staff by the addition of Dr. D. K. Barnes. He and Mr. Roger Ratcliffe of the Entomology Research Division are coleaders of our Beltsville team effort to develop weevil resistance. Our primary effort has been spent on developing testing procedures for identifying plants showing antibiosis to the alfalfa weevil. By combining several methods of screening, one can now evaluate many thousands of plants in the laboratory for mechanisms of resistance to several stages of the insects' life history. To test the same number of plants in the field would be prohibitive because of labor costs and availability of greenhouse and field space. The laboratory procedures have also made it possible to screen material throughout the year and to reduce the experimental errors usually present in biological testing. Steps in screening and evaluation are: 1. <u>Screening seedlings in cotyledon stage with adult weevils.</u> Seedlings are grown in growth chambers under high light intensities to reduce hypocotyl elongation. When seedlings are 12 days old they are infested with adult weevils. When all but 1 or 2 percent of the seedlings have been eaten, the weevils are removed and the remaining seedlings saved for further testing; 2. <u>Screening selected plants for adult leaf feeding</u>. Plants selected from step 1 are tested individually with adult weevils in order to determine the amount of leaf material eaten in a 20-hour

period. To facilitate the evaluation of this test, leaf disks instead of intact leaflets are used; 3. Screening plants for larval survival. Individual plants from step 2 are tested for larval survival. The larval survival test consists of infesting individual plants caged with a plastic cylinder with 10 freshly hatched larvae. Eight days later the weight and percentage of larvae surviving is determined and recorded; and 4. Screening plants for oviposition reaction. Plants which have been selected from either steps 2 or 3 are individually tested for absence of an oviposition stimulus.

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Executive Committee Meeting Minutes

W. B. Anthony, Presiding

The meeting of the Southern Pasture and Forage Crop Improvement Conference Executive Committee was called to order by Chairman W. B. Anthony at 12:10 p.m., June 15, 1966. The Chairmen (or their designated representative) and Past Chairmen of interest groups (1 vote per group) and officers of Southern Pasture and Forage Crop Improvement Conference, all constituting the Executive of SPFCIC, for the forthcoming year are as follows:

Group	Admin. Adv.	Past Chairman	Current Chairman
S-45	C. E. Barnhart	W. V. Chalupa	J. E. Moore
SFBG	O. B. Garrison	E. S. Horner	S. C. Schank
SFPEWG	R. L. Lovvorn	H. D. Gross	H. A. Fribourg

SPFCIC	Past-Past Chairman	C. Y. Ward
	Past Chairman	W. B. Anthony
	Chairman	H. A. Fribourg
	Chairman Elect	L. H. Taylor
	Chairman Elect-Elect	M. E. Riewe
	Permanent Secretary	R. C. Leffel

C. R. Owen was asked to comment on next year's program and he stated that the preferred date is about mid-April. All facilities are on campus if desired. A tour is planned to the Southeast Louisiana Experiment Station at Franklinton, (2 hrs. from Baton Rouge) and will require a day.

The need to coordinate technical group meetings with Southern Pasture and Forage Crop Improvement Conference was cited - - also S-45 may have other interests about mid-April.

C. Y. Ward suggested that the membership of Southern Pasture and Forage Crop Improvement Conference be polled for their wishes for next year's program. Franklinton was noted as east of Baton Rouge; perhaps the tour should be scheduled as the last day of the Conference.

H. A. Fribourg suggested arrangement of program by October. A discussion of program followed. Tentatively, the consensus was 1 day for technical groups and 2 days for Southern Pasture and Forage Crop Improvement Conference, the latter subdivided as follows: 1st day (1/4 day Admin. and work at L.S.U., 3/4 day interest groups or ?); 2nd day, tour.

Program correspondents for Louisiana State University will be C. R. Owen for Campus, H. B. Elzey for Franklinton, with each to receive copies of correspondence on all program.

H. D. Gross announced that North Carolina plans tentatively to extend an invitation to Southern Pasture and Forage Crop Improvement Conference for 1968 and suggested that the Chairman contact other States for future meetings, in logical order suggested by the summary of all past meeting sites (see page 37, 22nd SPFCIC Report, 1965). Gross commented that "the creeping alfalfa subject brings together the physiology and breeding groups whereas a subcommittee or the interest group, or whatever you want to call it, devoted to grazing research, both methodology and results, would be a good topic to draw together S-45 and the Physiology group."

The meeting was adjourned at 12:40 p.m.

REGISTRATION LIST - 1966

Name	State	Address
Anthony, W. B.	Alabama	Auburn University
Jordan, C. Wayne	"	P.O. Box 871, Auburn
King, Cooper, Jr.	"	Auburn University
Mays, David A.	"	Tennessee Valley Authority
White, Harlan E.	Colorado	Denver
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Moore, John E.	"	University of Florida
Ruelke, O. Charles	"	" " "
Schank, Stanley C.	"	" " "
Burns, Robert E.	Georgia	Georgia Agric. Expt. Sta.
Cummins, David G.	"	" " "
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Nelson, Billy D.	"	" " "
Owen, C. R.	"	" " "
Roark, C. B.	"	DeRidder
Carlson, Gerald	Maryland	USDA, Beltsville
Hanson, C. H.	"	" "
Hart, Richard H.	"	" "
Henson, Paul R.	"	" "
Hovin, Arne	"	" "
Moline, W. J.	"	University of Maryland
Van Soest, Peter J.	"	USDA, Beltsville
Leffel, Robert C.	"	" "
Browning, C. B.	Mississippi	Mississippi State University
Knight, William E.	"	" " "
Thurman, Wes	"	" " "
Ward, Coleman Y.	"	" " "
Blake, C. T.	North Carolina	North Carolina State University
Chamblee, Douglas S.	" "	" " " "
Gross, H. D.	" "	" " " "
Lovvorn, Roy L.	" "	" " " "
Timothy, David H.	" "	" " " "

Name	State	Address
Bates, Richard P.	Oklahoma	Noble Foundation, Ardmore
Griffith, Charles A.	"	" " "
Harlan, Jack	"	Oklahoma State University
McCroskey, Jack	"	" " "
Sotomayor, Antonio	Puerto Rico	University of Puerto Rico
Allen, L. R.	South Carolina	Clemson University
Beinhart, George	" "	" "
Chalupa, William	" "	" "
Gibson, Pryce B.	" "	" "
Jutras, M. W.	" "	" "
McClain, Eugene F.	" "	" "
Barth, Karl M.	Tennessee	University of Tennessee
Burns, Joe D.	"	" " "
Fribourg, Henry A.	"	" " "
Gray, Elmer	"	" " "
Montgomery, M. J.	"	" " "
Reynolds, John H.	"	" " "
Riewe, Marvin E.	Texas	Texas Agric. Expt. Station
Blaser, R. E.	Virginia	Virginia Polytechnic Institute
Boman, Ronald L.	"	Va. Forage Res. Sta.,Middleburg
Brown, R. H.	"	Virginia Polytechnic Institute
Dunton, H. L	"	" " "
Engel, R. W.	"	" " "
Fontenot, J. P.	"	" " "
Hammes, Roy C., Jr.	"	Va. Forage Res. Sta.,Middleburg
Huber, J. T.	"	Blacksburg
Jones, G. D.	"	Piedmont Res. Station, Orange
Lewis, W. W.	"	Virginia Polytechnic Institute
Martens, David C.	"	" " "
Mast, C. C.	"	" " "
McKee, W. H. Jr.	"	" " "
Miller, John D.	"	" " "
Mohror, Robert A.	"	" " "
Murley, W. Ray	"	" " "
Nichols, James R.	"	" " "
Obenshain, S. S.	"	" " "
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